FOREST PRACTICES
CODE

*of*
BRITISH COLUMBIA

# Forest Road Engineering Guidebook

Second edition

June 2002

BRITISH
COLUMBIA
Ministry of Forests

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# Foreword

This guidebook provides forest road practitioners with advice on road design and field practices to assist them to achieve the statutory and regulatory requirements in the *Forest Practices Code of British Columbia Act*, the *Forest Road Regulation*, and the *Operational Planning Regulation*.

The practices contained in this document are not mandatory and are not to be interpreted as the only acceptable options. However, as the Chief Engineer for the Ministry of Forests, I believe that by using the suggested procedures, a proponent will more likely be successful in addressing his or her legal responsibilities, at least where the actual site situation matches the conditions contemplated by the documented practices. The practices described in the document have been prepared and reviewed by experts in their field, including both public and private sector technicians and professionals. Accordingly, I believe this guidebook is a reasonable reflection of acceptable standards of practice in the forest sector of British Columbia.

Where a range of options or outcomes apply, such ranges have been given. Where these are not provided, some flexibility may be required in applying the guidebook practices, particularly where the proponent believes that such variance is warranted based on site-specific conditions.

Ron Davis, P.Eng.
Ministry of Forests
Chief Engineer - Senior Policy and Standards Engineer

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# Introduction

The materials presented in this guidebook are intended primarily for skilled, experienced, and knowledgeable technical personnel who are responsible for locating, designing, building, maintaining, and deactivating forest roads. It is aimed at those personnel who are already carrying out technical operations related to forest road engineering, but who may require guidance on how to interpret and meet the requirements of the *Forest Practices Code of British Columbia Act* (Act), and associated regulations. This guidebook is a result of many contributions from ministry staff and forest company practitioners, as well as a number of consultants.

Throughout this guidebook, emphasis is placed on compliance with operational and safety requirements and the need to ensure protection of forest resources, while meeting the requirements of the Forest Practices Code statutory obligations in an effective, efficient manner. The guidebook materials are grouped into six subject areas that correspond to the following work phases:

1. **Road Layout and Design**—This section describes route selection and layout, field investigation, surveying, and associated engineering practices to provide site-specific road location, design, and construction specifications.
2. **Design and Construction of Bridges and Stream Culverts**—This section outlines the general design requirements for bridges and stream culverts, and discusses non-professional and professional design responsibility, site and site survey information requirements for bridges and major culverts, preparation of construction drawings, specifications for bridges, major culverts, and stream culverts, and methods to estimate design flow discharge for streams.
3. **Road Construction**—This section presents information to assist technical personnel responsible for forest road construction and modification in constructing roads appropriate for the expected service life while minimizing any adverse impacts on other forest resources.
4. **Road Drainage Construction**—This section covers drainage system construction, the purpose of which is to maintain natural surface drainage patterns while intercepting, collecting, and controlling flows to minimize any adverse impacts to the environment.
5. **Road and Structure Inspection and Maintenance**—This section provides information to assist those responsible for the inspection and maintenance of roads and associated structures.
6. **Road Deactivation**—This section describes the objectives, levels, and techniques of forest road deactivation to provide practitioners with administrative and process-oriented guidance.

# 1. Road Layout and Design

## Introduction

Forest road layout and design is a process that includes route selection, field investigation, surveying, and analysis to provide a site-specific road location and design. Road design provides construction specifications, road prism geometry, stream crossing site information, and information necessary for construction control.

The detail and information required for each phase in this process varies with the type of road required, the complexity of terrain, the size and complexity of stream crossings, and other resource values.

This chapter:

- describes the types of projects for which the district manager's approval of road layout and design for construction and modification is mandatory
- provides information on route selection and layout, and describes the content requirements of a reconnaissance report
- provides criteria for survey level selection, and explains the types of survey (field traverse and location survey), and the suitability and application of different survey levels
- provides procedures for field traverses and location surveys
- explains general and geometric road design requirements
- provides example correction factors to convert compacted volume to bank volume for road design purposes
- discusses slope stability considerations if a proposed road will cross areas with a moderate or high likelihood of landslides
- provides road design specifications and parameters.

## District manager approval of road layout and design

The Ministry of Forests has developed a package of road layout and design forms and administrative procedures that incorporate the statutory contents for road layout and design. This information can be found at an appropriate Ministry of Forests website.

The district manager approves road construction and modification for forest roads under various permits. In general, unless the district manager requires it, the following types of projects are exempted from needing his or her approval of road layout and design:

- in-block roads, unless they cross areas with a moderate or high likelihood of landslides as determined by a terrain stability field assessment (TSFA), or unless they are in community watersheds and surface soil erosion potential or hazard is high or very high;
- stream-crossing modifications, unless the work consists of replacement or new construction of bridges or major culverts; and
- emergency works.

## Route selection and layout

Decisions made at the route selection stage may have long-term effects on road construction and maintenance costs, user safety, and other resources. Routes must be selected and located to meet the objectives of higher-level plans within the constraints of any approved operational plans or permits. It is essential that adequate time and resources be allocated to route selection.

The route selection stage begins with the collecting and analyzing of all available information for the development area, focusing on the route corridor. This information may include aerial photos, topographic maps, soil erosion potential maps, land alienation maps, and reconnaissance terrain stability or detailed terrain stability maps and other assessments for the area.

The method of harvesting and constraints of the harvesting system should also be considered if the road will traverse (1) a harvesting area or (2) an area that could be harvested in the future. Road drainage flows and drainage structures and road and clearing widths could all be affected by harvesting.

Control points (physical features that may influence road location or design) should then be plotted on the aerial photos and/or topographic maps of a suitable scale.

Control points include:

- stream crossings, rock bluffs, benches, passes, saddles, and other dominant terrain features
- road grades and switchback locations
- harvesting system landings
- potential endhaul or waste areas
- alienated lands, including powerline, gas pipeline, or railway crossings
- current access and junction to existing roads.

Route selection should then be made based on an analysis of all of the available information, and the route should be field verified.

The route selection field phase is an on-the-ground check of the proposed route or potential routes, taking into consideration control points or other constraints. This field traverse is also known as a Level 1 survey (measurements are not usually accurate enough for detailed road design) and is run along a proposed route to confirm that the horizontal and vertical alignment are suitable. Adjustments to the line may be necessary, and often several iterations are needed to establish the alignment and confirm the choice of route.

The person carrying out the field traverse should make sufficient notes to prepare a detailed reconnaissance report to assist the location surveyors, road designers, and road builders.

The reconnaissance report should identify and or confirm:

- terrain conditions and road sections that are in unstable or potentially unstable terrain
- road sections with side slopes over 60% or where slope instability is found
- control points and topographic features (e.g., rock bluffs, swamps, avalanche paths, landslides, and debris slides), including those that may be used as photo ties
- the sections of road that encroach on public utilities
- the sections of road that are adjacent to or cross private property, Crown leases, or mineral and placer claims or leases (where possible, alienated lands should be avoided)
- all continuous and intermittent drainage flow channels, springs, seeps, and wet areas
- riparian areas
- stream crossings where channel and bank disturbances can be prevented or mitigated, locations that require site plans, and data required for minor stream crossings
- forest cover (species composition, timber quality, and volume per hectare)
- recommended slash and debris disposal methods and additional clearing widths required for the slash and debris disposal
- soil types based on visual observations of exposed cuts, shallow hand-dug test holes and probing, and the location of these soils on maps or aerial photos (see Appendix 1 for a method of identifying soils)
- maximum road grades and minimum curve radii
- location and extent of bedrock, if rippable, and the potential as ballast
- location and extent of gravel sources and the potential for use as subgrade and surfacing materials

- endhaul sections and potential waste areas
- recommended construction methods and potentially appropriate alternatives
- recommended survey level or levels appropriate for the terrain.

The field reconnaissance report should also record the characteristics of existing roads in the vicinity of the proposed road location by identifying and recording soil types, stable cut and fill slope angles, and existing sources of road surfacing materials.

Field reconnaissance is an appropriate stage to evaluate the need for any additional information or assessments that may include:

- TSFAs
- riparian classification of streams, wetlands, and lakes
- identification of fish streams in community watersheds
- visual impact assessments
- archaeological impact assessments
- soil erosion field assessments.

## Survey level selection

There are two general types of surveys: a field traverse and a location survey. There are also four levels of survey intensity: Survey Levels 1, 2, 3, and 4. These survey types and levels are briefly explained below.

To determine which survey type and level to recommend in the reconnaissance report, the physical characteristics of the terrain, design complexity, and desired road prism geometry should be considered.

### *Types of survey*

#### Field traverse

A field traverse is required for road layout and design and is conducted to collect data and measurements for the road location. A field traverse is also sometimes referred to as Survey Level 1 (see "Survey levels" below).

#### Location survey

A location survey is carried out to obtain information and measurements necessary for detailed design, or to obtain information when geometric road designs are required. Compared to a field traverse, a location survey is carried out at a higher level of survey intensity (i.e., Survey Level 2, 3, or 4).

If as-built surveys are required for volume determination or to check conformance to the design, the location survey level should be suitable for accurately re-establishing the road centreline location.

If construction surveys are required, the location survey level should be suitable to accurately re-establish the construction control points.

The accuracy achieved with any survey level depends, in part, on the type and condition of survey equipment used, the competence of the crew, and the field methods used. Global Positioning System (GPS) receivers, like other survey equipment, are acceptable when they can achieve the required horizontal and vertical accuracy for the appropriate survey level.

Stream crossings require special consideration. Site information requirements for bridge and culvert planning and design are provided later in this chapter.

Winter-constructed roads require special layout considerations to identify the location of cross-drains and stream crossings. Long continuous grades should be avoided, since they easily become conduits for meltwater and groundwater seepage. Steep cut banks should be avoided because they may slough or fail, blocking ditches and sending ditchwater onto the road surface and creating the potential for major surface erosion.

## *Survey levels*

The following criteria are used to determine the appropriate survey level for a field traverse (Survey Level 1) or location survey (Survey Levels 2, 3, or 4).

### Survey Level 1 (for field traverses)

*Application*: For field traverses on stable terrain with a low likelihood of landslides and where geometric road design, construction surveys, and as-built surveys are not required. The necessary accuracy of survey may be achieved with basic field equipment such as hand compass, clinometer, and hip chain.

*Horizontal accuracy*: Turning points are established to a relative accuracy of 1:100.

*Vertical accuracy*: Not applicable.

### Survey Level 2 (for location surveys on stable terrain)

*Application*: For location surveys on stable terrain with a low likelihood of landslides and where a geometric road design, construction surveys, or as-built surveys are desired.

*Horizontal accuracy*: Turning points to be established to a relative accuracy of 1:300.

*Vertical accuracy*: = $\sqrt{\text{total horizontal distance measured in kilometres}}$, expressed in metres. For example, the vertical accuracy for a 1-km road is 1 m. For a 2-km road, the vertical accuracy is 1.41 m.

### Survey Level 3 (for location surveys within areas of moderate or high likelihood of landslides)

*Application*: For location surveys, construction surveys, geometric road design, and as-built surveys in areas of moderate to high likelihood of landslides as determined by a TSFA. Appropriate level of survey for material volume determination and detailed-engineered estimates. This level of survey may also be used for bridge and major culvert planning and design, but greater vertical accuracy would possibly be necessary.

*Horizontal accuracy*: Turning points to be established to a relative accuracy of 1:1000.

*Vertical accuracy*: = $0.5 \times \sqrt{\text{total horizontal distance measured in kilometres}}$, expressed in metres. For example, the vertical accuracy for a 1-km road is 0.5 m. For a 2-km road, the vertical accuracy is 0.71 m.

### Survey Level 4 (for high-order survey requirements)

*Application*: A high-order survey for location surveys, construction surveys, construction contracting on a cost-per-unit basis, check surveys, placement of permanent bridges, as-built surveys through Crown leases, mineral and placer claims, and leases, private property, and surveys to re-establish private property lines.

*Horizontal accuracy*: Turning hubs are to be established to a relative accuracy of 1:5000.

*Vertical accuracy*: = $0.3 \times \sqrt{\text{total horizontal distance measured in kilometres}}$, expressed in metres. For example, the vertical accuracy for a 1-km road is 0.3 m. For a 2-km road, the vertical accuracy is 0.42 m.

## Procedures for field traverses and location surveys

This section outlines the minimum requirements for field traverses and location surveys. Although considerable gains have been made in survey instrumentation technology, use of the technology does not preclude the need to follow standard survey practices. Standard practices are outlined in the *Manual for Roads and Transportation* (BCIT 1984).

## *Survey Level 1 (for field traverses)*

Where no location survey is required (e.g., where a proposed road will **not** cross areas with a moderate or high likelihood of landslides as determined by a TSFA):

1. Clearly identify the beginning and end of the road.
2. Clearly flag the proposed centreline of the road.
3. Using an appropriate method (such as aluminum plaques and tree blazes), mark and record control points, noting the control point number, station, bearing, and horizontal distance from the proposed centreline.
4. Record notes on forest cover, vegetative types, soil types, rock, ground water seepage, streams, etc.

## *Survey Levels 2 and 3 (for location surveys)*

### Traverse

1. Clearly identify the beginning and end of the road.
2. Establish intervisible stations called turning points (TPs) if using a compass or traverse hubs if using a transit—along the preliminary centreline (P-Line). Use manufactured stakes or local material (blazing of saplings) driven into the ground.
3. Measure the bearing, slope gradient, and distance between TPs and mark the cumulative chainages and/or point number in the field.
4. Measure the slope gradient and distance to additional grade breaks between TPs as intermediate fore shots to facilitate taking cross-sections at those locations.
5. Using an appropriate method (such as aluminum plaques and tree blazes), mark and record control points, reference points and bench marks, noting the number, station, bearing, and horizontal distance from the P-Line.
6. Record notes on forest cover, vegetative types, soil types, rock, ground water seepage, streams, etc. that were not identified on the reconnaissance report.
7. Obtain enough information to ensure that road junctions can be designed and constructed. Switchbacks located on steep slopes also require detailed data for proper design and construction.
8. The final designed road location centreline (L-Line) should be close to the P-Line and generally within 3 m of the P-Line if the road will cross areas with a moderate to high likelihood of landslides as determined by a TSFA, or if bedrock is present or switchbacks are encountered.

## Cross-sections

1. Take cross-sections at all TPs and intermediate fore shots perpendicular to the back tangent or bisecting the interior angle of two tangents. Ensure that the recorded information is compatible with computer design software requirements.
2. Cross-sections should not be more than 15 m apart in rock or 30 m apart in other material. A longer spacing will not provide sufficient cross-sections for the accurate earth volume calculations required for geometric design. Exceptions to this guideline may be considered for Level 2 surveys conducted in uniform terrain.
3. Extend cross-sections at least 15 m horizontally on either side of the location line or farther to accommodate the road prism and in areas considered for waste disposal.
4. Measure and record slope breaks (over 10%) on the cross-section profile to the nearest 0.1 m in distance and nearest 1% in slope gradient.
5. Take additional cross-sections to record features that may affect the road prism on each side of the proposed centreline. Examples of such features are rock outcrops, flat topography (benches), lakeshores, fences, streams, back channels, and existing roads.

## Referencing and benchmarks

A reference tree or other fixed object (e.g., bedrock outcrop) is used for the horizontal control, and a benchmark is used for the vertical control of the road traverse. Both are important for re-establishing the designed location line (L-Line), and are required for construction surveys and those surveys necessary to complete as-built documentation.

1. Reference the beginning and end of the location line traverse. When switching from one survey level to another, reference this point in accordance with the higher survey level accuracy.
2. Establish references at least every 300 m, and at control points established during the field traverse.
3. Use two trees to establish references outside the proposed upslope clearing limit. Set the angle from the TP to the two reference trees between 60° and 120° from the centreline tangent. Make horizontal measurements to the centre of the reference marker (plaque). (The use of two reference trees improves the accuracy of relocating the traverse station and provides for a back-up if one tree is destroyed.) Use the same level of survey accuracy to establish references and benchmarks.
4. Record the diameter at breast height (dbh) and species of the reference trees so that they can easily be found.

5. Establish benchmarks outside the clearing width no more than 1 km apart, at major structures and at existing references for control points established during the field traverse.
6. A typical benchmark and road survey reference information is shown in Figure 1.

### Ties to existing property boundaries

Traverse-tie the location survey to existing property markers or other evidence of legal boundaries that may be near the location survey. Sufficient investigation should be completed to establish the location of the property line and determine whether the road right-of-way will encroach on the property line. If possible, the centreline and right-of-way should be relocated if there is an encroachment.

## *Survey Level 4 (for high-order survey requirements)*

As noted earlier, this high-order survey is also suitable for alienated lands such as private property. Before starting work on alienated lands, contact the owners and explain the nature of the work. The owner may be able to provide the location of corner pins and other useful information.

When working on alienated lands, keep the clearing (tree falling, line slashing, etc.) and marking of lines to a minimum. The following information should be recorded and tied to the location line traverse:

- all existing legal markers
- improvements and utilities that may be affected by the right-of-way
- fences and buildings
- parts of the existing road if applicable, including the top of cut, toe of fill, grade, and ditchline.

If possible, close traverses onto at least two legal posts to ensure accuracy and establish correct orientation of the survey with respect to the legal lot or lots.

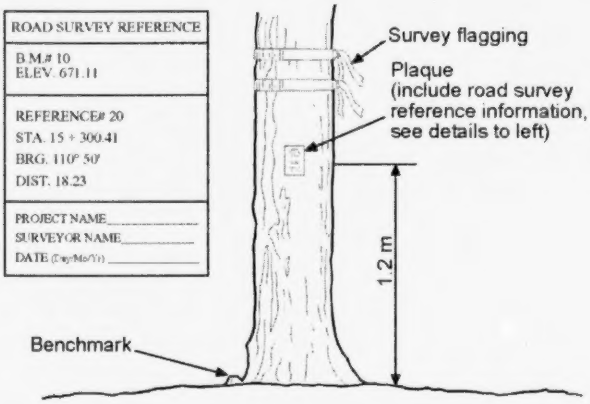
ROAD SURVEY REFERENCE
B.M.# 10
ELEV. 671.11
REFERENCE# 20
STA. 15 + 300.41
BRG. 110° 50'
DIST. 18.23
PROJECT NAME
SURVEYOR NAME
DATE (Day/Mo/Yr)
Survey flagging
Plaque (include road survey reference information, see details to left)
1.2 m
Benchmark

**Figure 1.** Typical benchmarks and reference.

## Road design requirements

The purpose of road design is to produce design specifications for road construction by determining the optimum road geometry that will accommodate the design vehicle configuration for load and alignment, and traffic volume, and provide for user safety, while minimizing the cost of construction, transportation, maintenance, and deactivation. The optimum road design should minimize impacts on other resources by minimizing clearing and road widths, minimizing excavation, using rolling grades, and installing proper drainage structures.

Road design software has been developed to replace manual drafting and repetitious design calculations so that various alignment alternatives can be quickly evaluated. Once the location survey data have been entered into the road design program, select and input appropriate design parameters for the specific project. Ensuring this requires direction from a skilled and knowledgeable designer familiar with forest road layout, design, and construction practices. As each phase of road layout and design builds on the previous phase, the quality of the final design depends on the appropriateness of the road location, field data, and survey—and the competence of the designer.

### *General design requirements*

This section provides road design requirements common to all levels of road layout and design. Construction techniques, road width, cut and fill slope angles, and horizontal and vertical control angles are selected according to terrain and soil conditions for the required road standard. Forest road standards are defined primarily in terms of stabilized road width and design speed.

Road design specifications consist of alignment elements (e.g., horizontal curvature, vertical curvature, road grade, and sight distance) and cross-section elements (e.g., full or partial bench construction, sidecast construction, road width, angles of repose for stable cut slopes, ditch dimensions, drainage specification, and clearing widths).

Geometric road designs include plans, profiles, cross-sections, and mass haul diagrams showing the optimum balance of waste, borrow, and endhaul volumes. The designs are generated from the route selection process and the location survey. From the location survey information, a road centreline (L-Line) is designed for vertical and horizontal alignment, earthwork quantities are calculated, and a mass haul diagram is produced to show the optimum placement of excavated material.

Figure 2 shows a typical road cross-section and the terminology used to describe cross-section elements.

## Factors to consider in road design

Road design should consider the following factors:

*General considerations:*

- intended season and use of the road (design vehicle configuration for load and alignment, and traffic volume)
- climate (heavy snowfall areas, heavy rainfall areas, etc.)
- design service life of the road
- user safety
- resource impacts
- economics
- road alignment (horizontal and vertical geometry)
- junctions with existing roads
- road width (turnouts and widenings).

*Soils, road prism geometry, slash disposal:*

- the measures to maintain slope stability if the road will cross areas with a moderate or high likelihood of landslides (also see "Geometric road design requirements" below)
- soil types (including the use of appropriate conversion factors to adjust for swell and shrinkage of materials)
- cut and fill slope angles
- clearing widths
- slash disposal methods

- planned movement and placement of materials (balancing of design), including waste areas and endhaul areas.

*Drainage, construction techniques, sediment prevention, road deactivation:*

- culverts (locations, type, size, and skew angles)
- drainage and ditch (including depth) locations
- rock blasting techniques to optimize usable rock
- anticipated construction problems
- measures to mitigate soil erosion (including vegetative requirements and prescriptions)
- measures to maintain water quality
- future deactivation requirements.

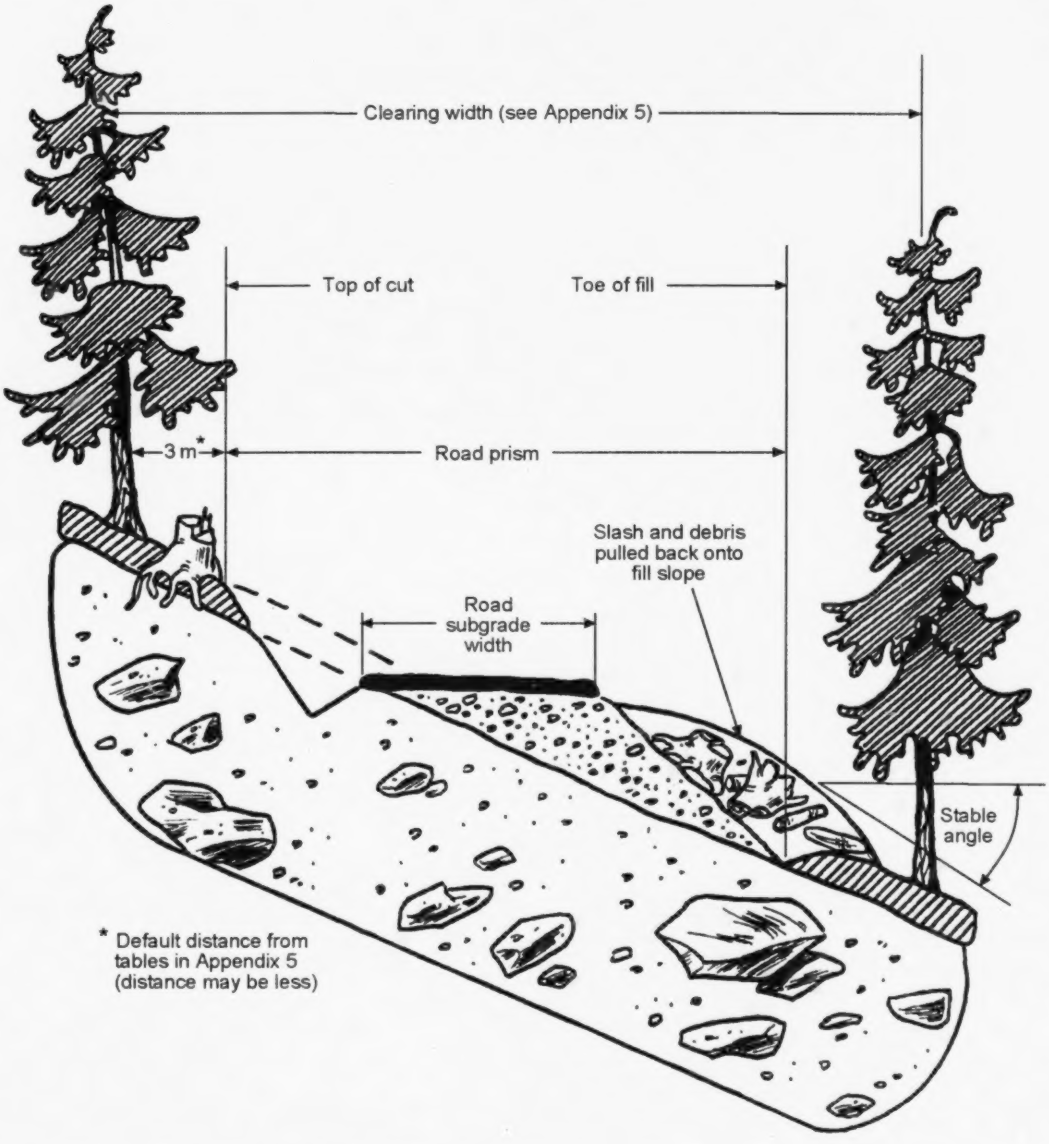
Clearing width (see Appendix 5)
Top of cut
Toe of fill
3 m*
Road prism
Slash and debris pulled back onto fill slope
Road subgrade width
Stable angle
* Default distance from tables in Appendix 5 (distance may be less)

**Figure 2.** Typical roadway on moderate slopes with no additional clearing.

## Geometric road design requirements

A geometric road design is mandatory for all roads that will cross areas with a moderate or high likelihood of landslides as determined by a TSFA. In these areas, it is also mandatory that measures to maintain slope stability be incorporated into the geometric road design. These measures rarely allow for the most optimum balance of waste, borrow, and endhaul volumes.

In geometric road design, specifications such as road width, cut and fill slope angles, and horizontal and vertical control angles are selected to match the required road standard. A road centreline location (L-Line) is designed based on information from the location survey and reconnaissance report. Earthwork volumes or quantities are then calculated.

In addition to the information described under "General design requirements" above, a geometric road design should also provide:

- plans and profiles (see Appendix 3 for recommended content and layout)
- cross-sections with road prism templates
- mass diagrams with balance lines
- correction factors used in the design to convert compacted volume to bank volume
- a schedule of quantities and units of measure for clearing, grubbing, excavating (other material and rock), and gravelling
- planned movement and placement of materials (balancing of design)
- the location and size of required drainage structures such as culverts and bridges
- the location and size of retaining walls or specialized roadway structures
- clearing widths
- typical construction equipment required, and any equipment recommended for specialized construction techniques
- estimated material and construction costs
- location survey alignment and designed centreline (L-Line) offsets, and clearing width offsets shown on the site plan
- slope stake information (note that this information is only a guide and slope/grade stakes should be calculated and placed based on design or re-design of cuts and fills at centreline)
- measures required for reducing potential impacts on other resource values
- site-specific design and construction notes and prescriptions on, for example, the location of endhaul sections, borrow pits, waste and slash disposal areas, and full bench cut areas, and any other information that the designer considers useful to the road builder

- measures to maintain slope stability if the road will cross areas with a moderate or high likelihood of landslides as determined by a TSFA
- information that the designer considers useful to the road builder or owner.

Whenever possible, the design should allow for the use of waste or spoil material in ways that reduce endhauling requirements. For example, some material types may be used for the road subgrade, base course, turnouts, curve widenings, and embankment (fill). If these options are not available, or if the excess material consists of overburden and debris, then spoil sites should be identified as close to the construction area as possible. Abandoned quarries, gravel pits, and roads are some possibilities. Alternatively, stable areas in gentle or benched terrain can be evaluated for use as spoil sites.

## Correction factors to adjust for swell and shrinkage of materials

### *Material volumes (bank, loose, and compacted)*

The volume of natural in-place material usually expands (swells) or contracts (shrinks) after it is excavated and reworked. Figure 3 illustrates how the volume of a material can change during excavation, handling, placement, and compaction in a fill. Soil and rock volumes can be expressed in different ways, depending on whether they are measured in the **bank**, or measured in **loose** or **compacted** conditions.

**Bank volume** (sometimes referred to as **excavation volume**) is the volume of material in its natural, or in-place, condition.

**Loose volume** (sometimes referred to as **trucked volume**) is the volume of material in a loose, broken, blasted, or otherwise disturbed state that has been excavated and stockpiled or loaded into trucks and hauled (handled). As shown in Figure 3, both soil and rock increase in volume (swell) when they are excavated and handled. This occurs because air voids are created in the material during these processes.

**Compacted volume** (sometimes referred to as **embankment volume**) is the measured volume of material after it has been placed in a fill and compacted. As shown in Figure 3, when loose material is placed and compacted, a reduction in volume occurs. The amount of this decrease may be greater or less than the increase in volume due to excavation, depending on several factors explained below. If the compacted volume is greater than the bank volume, the volume increase is called **swell**. If the compacted volume is less than the bank volume, the volume reduction is called **shrinkage**.

The amount of swell and shrinkage depends on several factors:

- soil or rock type
- natural in-place density
- moisture content of the loose material at the time of placement and compaction
- compactive effort applied to the fill material.

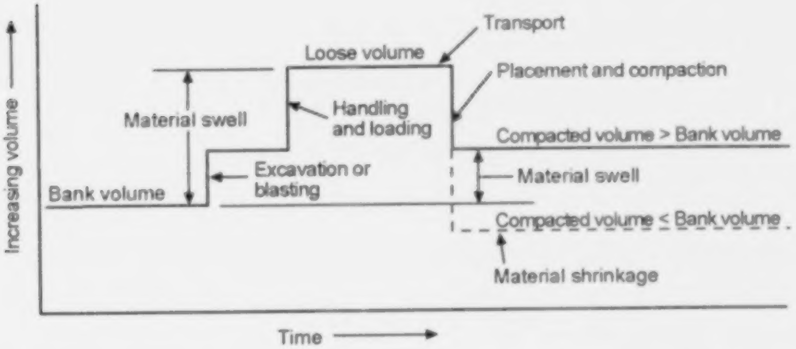
Transport
Loose volume
Placement and compaction
Handling and loading
Material swell
Compacted volume > Bank volume
Excavation or blasting
Material swell
Bank volume
Compacted volume ≤ Bank volume
Material shrinkage
Increasing volume
Time

**Figure 3.** Example of material volume variation with time for various stages of road construction. Not to scale.

### *Example correction factors*

If the objectives of road design are to optimize the balance of excavated, fill, waste, and endhaul volumes and to minimize volume movements, the road designer should adjust material volumes to compensate for swell and shrinkage.

Table 1 shows example correction factors for various material types, to convert compacted volume to bank volume for use in road design.

In road design, material volumes are most commonly reported in volumes equivalent to bank volumes, because road construction projects are usually estimated, contracted, and paid based on bank volumes. In this system:

- Cut and fill volumes are both reported as the volumes they would occupy in the bank.
- The cut volume is the bank volume calculated from the road cross-sections, and therefore no adjustment is required.
- To convert the compacted fill volume back to the bank volume, a correction factor for swell and shrinkage must be applied. The correction factor is <1 to compensate for swell and >1 to compensate for shrinkage. If no net swell or shrinkage occurred during excavation, handling, placement, and compaction, the correction factor is 1.0.

The correction factors in Table 1 do not include any effects due to wastage or loss of material. The road designer should consider the need to separately account for other potential material losses that might affect achieving a balanced cut and fill design. Typical important sources of material loss, among others, can include:

- material lost (spilled) in transport from cut to fill, and
- subsidence, compression, or displacement of the prepared subgrade or original ground surface caused by the weight of the overlying embankment.

**Table 1.** Example correction factors to convert compacted volume to bank volume for various materials.

| Example Correction Factor | Swell or Shrinkage | Example Material When It Was IN THE BANK |
|---|---|---|
| 0.75 to 0.85 | Swell | **Solid rock.** Assumes drilling and blasting is required, resulting in large fragments and high voids. |
| 0.9 to 1.0 | Swell | **Dense soil or rippable rock.** In the case of dense soil (e.g., glacial till) or rippable rock, typical compaction during conventional forest road construction will result in swell. |
| 1.0 to 1.15 | Shrinkage | **Compact to loose soil.** Lower correction factors are more appropriate for coarse-grained soils (e.g., sand, sandy gravel, or mixtures of gravel, sand, silt, and clay). Higher correction factors are more appropriate for fine-grained soils (e.g., silt and clay). It is more possible to achieve shrinkage during conventional forest road construction if the soil in the bank was in a loose condition. For example, a correction factor of 1.0 (i.e., no shrinkage) may be appropriate for compact sands and gravels, whereas a correction factor of 1.15 may be appropriate for very loose silts. |

**Notes:**

1. The "example correction factors" are applicable to forest road design purposes only. They assume compaction typically achieved during conventional forest road construction, and different correction factors could apply for engineered fills, placed and compacted to achieve the highest material density possible. Because of the variability of natural materials and their conditions in the bank, the potential for material loss during handling, and the range of road construction methods, correction factors are best determined from experience and local knowledge.
2. The example correction factors are based on swell or shrinkage effects due to an increase or decrease in the density of the soil or rock materials, and do not include any effects of potential wastage or loss of material from other sources.

### Example

Bank volume = compacted volume × correction factor.

Example: If the compacted volume of shot rock is 12 $m^3$ measured from drawings, how much bank volume needs to be drilled, blasted, and excavated to achieve this volume? Assume a correction factor of 0.75.

Solution: Bank volume = $12\ m^3 \times 0.75 = 9\ m^3$

## Slope stability considerations

Roads should be designed, constructed, maintained, and deactivated so that they will not contribute directly or indirectly to slope failures or landslides.

If a proposed road will cross areas with a moderate or high likelihood of landslides as determined by a TSFA, the person required to prepare the road layout and design must address, among other requirements, **measures to maintain slope stability**. (The term "measures" means prescriptions or recommendations.) For roads that cross such terrain, a conventional cut and fill road construction technique may not be an adequate type of measure to maintain slope stability, and alternative measures incorporated into the geometric road design may be needed to prevent road-induced slope failures and landslides.

Examples of types of prescriptions or recommendations include:

- road relocation, or a decision not to build
- **road construction techniques**
- methods to cross gullies and fish streams
- cut and fill slope angles
- location and design of spoil or waste areas and endhaul areas
- drainage control or installation of subsurface drainage
- road modification, maintenance, and deactivation strategies.

Examples of different **road construction techniques** include:

- for single season use of the road, ½ bench construction with no endhaul, followed by full pullback of road fill after harvesting
- oversteepened fills for single-season use of the road
- use of wood for fill support for short-term roads
- oversteepened cuts with modified drainage control to manage minor sloughing

- ¾ bench construction with endhaul and replacement of finer material with coarse rock fill
- full bench construction with 100% endhaul and water management following harvesting
- designed retaining wall structures to support cut or fill slopes
- designed fills that incorporate special requirements for compaction of the fill or reinforcement of the fill with geosynthetics.

### *Involvement of qualified registered professionals*

If a proposed road will cross areas with a moderate or high likelihood of landslides as determined by a TSFA, the measures to maintain slope stability must be prepared by a **qualified registered professional** as defined in the Forest Road Regulation. Additionally, a qualified registered professional must sign and seal a statement that indicates that the proposed measures to maintain slope stability have been incorporated into the geometric road design. Obviously, the qualified registered professional should have the training and/or experience to be able to determine if the measures have been incorporated into the geometric road design. This individual may or may not be the same person who prepared the measures.

A qualified registered professional should ensure that his or her prescriptions or recommendations are site specific and precise so that the road designer cannot misunderstand them. He or she should also provide the results of the measures to maintain slope stability as they apply to the road prism, or adjacent to the road prism, separately from other recommendations. For example, recommendations for bridge foundations, walls, or deep approach fills should be provided in a separate report or, alternatively, in distinct sections or under separate headings in the same report, so that the two sets of recommendations cannot be confused.

Specific measures should be referenced to road traverse survey stations marked in the field.

### *Statement of construction conformance*

The prescriptions or recommendations must state whether or not a qualified registered professional should prepare a **statement of construction conformance** after construction to confirm that the measures were incorporated into the construction. Such a statement may be necessary if the measures are technically complex or if they are not readily discernible after the construction is complete. It may require a qualified registered professional, or his or her designate, to be on site during construction. The statement of construction conformance does not have to be prepared by the same qualified registered professional who prepared the prescriptions or recommendations.

Refer to the Ministry of Forests package of road layout and design forms that incorporate the above statutory content requirements. This information can be found at an appropriate Ministry of Forests website.

Additional guidelines for preparing and implementing measures to maintain slope stability are available in several Forest Regions.

## *Criteria for measures to maintain slope stability*

If a proposed road will cross areas with a moderate or high likelihood of landslides as determined by a TSFA, the person required to prepare a road layout and design must ensure that it includes measures to maintain slope stability that satisfy either **Criterion 1 (hazard-based) OR Criterion 2 (risk-based)**. These criteria are explained below, and are consistent with the requirements of Section 6 (1)(n)(i) and (ii) of the Forest Road Regulation.

### Criterion 1

| | |
|---|---|
| Code Requirement: | In this criterion, the selected measure is the **least likely measure to result in a landslide**, and a qualified registered professional provides a statement to this effect. (See Section 6 (1)(n)(i) of the Forest Road Regulation.) |

Criterion 1 is considered to be hazard-based (hazard being the likelihood of landslide occurrence). It requires consideration of a limited number of **road construction techniques** that are likely to result in the lowest likelihood of landslide occurrence. Meeting this criterion would be justified in areas where the likelihood of landslide occurrence is high, and where any measure other than the "least likely measure to result in a landslide" would be unacceptable to a district manager.

A measure that would satisfy the above criterion is any prescription or recommendation for a road construction technique that will result in **at least a low likelihood** of a landslide occurring. A qualified registered professional must provide a statement to this effect to accompany the prescriptions or recommendations. No other road construction techniques other than the ones that provide for at least a low likelihood of landslide occurrence should be considered. There are usually only a few methods of road construction that fit this criterion, and most involve higher road costs. Obviously, the selected measure should be considered in the context of conventional practices for forest roads.

Examples of least likely measures to result in a landslide include any road construction technique that has a low or very low likelihood of landslide occurrence, such as:

- full bench construction in competent bedrock and 100% endhaul of the excavated material
- construction of an engineered retaining wall structure to fully support a road embankment fill or a cut slope
- the application of an engineered reinforced earth section to strengthen and maintain the stability of a deep embankment fill.

In this criterion, the optimization of total costs for road building, maintenance, and deactivation over the life of the road is typically secondary to providing assurance to the district manager that the road construction technique will result in a low or very low likelihood of a landslide occurring.

Appendix 10 shows a procedure for assessing and reporting landslide hazards. **Note:** *The Landslide Hazard table in Appendix 10 is an illustrative example only and should not be considered a procedural standard.*

## Criterion 2

| | |
|---|---|
| Code Requirement: | In this criterion, the selected measure is based on an analysis (i.e., landslide risk assessment) made by a qualified registered professional. (See Section 6 (1)(n)(ii) of the Forest Road Regulation.) |

Criterion 2 is considered to be risk-based (risk being the product of hazard and consequence: Risk = Hazard × Consequence). This criterion considers measures that are likely to result in the **lowest risk of damage to one or more elements at risk**. In this criterion, there is usually a broader range of possible types of measures and different combinations of measures to consider than that permissible under Criterion 1.

The selected measures are based on a **landslide risk assessment** (see the definitions below) made by a qualified registered professional. A landslide risk assessment involves identifying reasonable road construction technique options and other potential mitigative measures that could be incorporated into the design, construction, maintenance, or deactivation of the road. The alternatives should focus on achieving an optimum balance between road costs and level of risk—a balance that is satisfactory to the district manager.

For each road construction technique or other type of measure, a **qualitative landslide risk assessment** involves the comparison of:

1. likelihood of landslide occurrence (hazard)
2. potential consequences of a landslide (consequence)
3. resultant risk (Risk = Hazard × Consequence)
4. all direct and indirect costs.

Items 1, 2, and 3 are the **landslide risk analysis**; item 4 is the **evaluation of landslide risk**. Items 1 through 4 together make up the **landslide risk assessment**.

Appendix 10 provides a procedure for carrying out a **qualitative landslide risk analysis** to determine landslide hazard, landslide consequences for various elements at risk, and landslide risk. *The tables and matrix in Appendix 10 are illustrative examples only and should not be considered a procedural standard.*

For most projects, the entire landslide risk assessment, including the selection of the optimum measure, can be carried out in the field. For less routine projects, and in addition to the fieldwork, it may be necessary to carry out a detailed office-based cost comparison of each alternative **(evaluation of landslide risk)**. For effective and efficient risk management decisions to be made, such comparisons should also take into account the residual risk (the risk that remains after the measures have been implemented) and the costs of road maintenance and deactivation over the expected life of the road.

For some special projects, it may be necessary to determine the nature and costs of any remedial actions required should a landslide occur. Such actions might include any potential rehabilitation of aquatic habitats, recovery of timber values, and replacement of road or other infrastructure damaged from a landslide. The costs for these actions would be added to the other costs described above.

It is important that users realize that decisions with respect to hazard, consequence, and risk may need to be undertaken by a team of individuals familiar with the various parameters and factors involved in landslide risk assessment. For example, a qualified registered professional alone may not always have enough knowledge (e.g., about all the elements at risk and associated costs) to carry out a complete landslide risk assessment. Sometimes the qualified registered professional will only be able to estimate and describe the likelihood of landslide occurrence and the potential **landslide characteristics**, such as the likely path of the landslide, dimensions of the transportation and deposition areas, types of materials involved, and the volumes of materials removed and deposited. In these cases, it is often the role of the person responsible for the road layout and design to use the landslide characteristic information to determine the landslide consequences, with assistance from specialists as necessary. For example, where the element at risk is a fish stream, a fisheries specialist may have to assess the consequences and risks associated with a potential landslide.

See the "Suggestions for further reading" at the end of this chapter for helpful references on landslide risk assessment.

***Definitions***

The following definitions have been adapted from the CAN/CSA-Q850-97.

**Landslide risk analysis** is a systematic use of information to determine the landslide hazard (likelihood of landslide occurrence) and consequence of a landslide at a particular site, thereby allowing an estimate of the risk to adjacent resources from a landslide occurrence.

**Evaluation of landslide risk** is the process by which costs or benefits of various road construction options are compared by the proponent and evaluated in terms of tolerable risk considering the needs, issues, and concerns of those potentially affected by the landslides.

**Landslide risk assessment** is the overall process of landslide risk analysis and the evaluation of landslide risk (landslide risk assessment = risk analysis + evaluation of risk). Landslide risk assessment is an essential component of assessing the advantages and disadvantages of various road construction options and other measures to maintain slope stability.

## Design specifications and parameters

### *Road alignment*

Road design incorporates horizontal and vertical road alignments that provide for user safety. This involves establishing:

- appropriate travel speeds
- suitable stopping and sight distances
- road widths
- turnouts
- truck and trailer configurations
- appropriate traffic control devices.

Designed travel speeds often vary along forest roads due to terrain conditions or changing road standards. The cycle time or distance from the logging area to the dump or processing area may be an important economic factor to consider in establishing an overall design speed, and may be derived from a transportation study and stated in the overall plan for the area. In other cases, topography and terrain will dictate alignment, with little impact from other factors. In general, the safe vehicle speed for a road should be based on:

- horizontal and vertical alignment of the road
- super-elevation on curves
- coefficient of friction between tires and road surface

- type and condition of road surface
- road width
- sight distance and traffic volume.

Tables 2 and 3 and Appendix 2 can be used to determine appropriate travel speeds and stopping and sight distance requirements along the road and at road junctions.

Turnouts should be located in suitable numbers (intervisible and often three or more per kilometre) on single-lane roads to accommodate user safety. The recommended lengths and taper widths for turnouts, based on stabilized road width, can be determined from Table 4.

The *Manual of Geometric Design Standards for Canadian Roads*, published by the Roads and Transportation Association of Canada (RTAC) provides design standards that can be used for forest roads.

**Table 2.** Summary of alignment controls for forest roads.

| Stabilized Road Width (m) | Design Speed (km/h) | Minimum Stopping Sight Distance[a] (m) | Minimum Passing Sight Distance for 2-Lane Roads (m) | Minimum Radius of Curve (m) | Suggested Maximum Road Gradient[b,c] | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Favourable | | Adverse | | |
| | | | | | S | P[d] | S | P[e] | Switchbacks |
| 4 | 20 | 40 | | 15 | 16% | 18% for distance <150 m | 9% | 12% for distance <100 m | 8% |
| 5–6 | 30 | 65 | | 35 | 12% | 14% for distance <150 m | 8% | 10% for distance <100 m | 8% |
| | 40 | 95 | | 65 | | | | | |
| 8+ | 50 | 135 | 340 | 100 | 8% | 10% for distance <200m | 6% | 8% for distance <100m | 6% |
| | 60 | 175 | 420 | 140 | | | | | |
| | 70 | 220 | 480 | 190 | | | | | |
| | 80 | 270 | 560 | 250 | | | | | |

**NOTE:** These are suggested alignment controls for average conditions on forest roads. Variations can be expected, depending on, for example, site conditions and time of use.

[a] For two-lane and single-lane one-way roads, multiply the minimum stopping sight distance by 0.5.

[b] There are no absolute rules for establishing maximum road gradient. Maximum grades cannot generally be established without an analysis to determine the most economical grade for the site-specific conditions encountered. The maximum grade selected for design purposes may also depend on other factors such as: topography and environmental considerations; the resistance to erosion of the road surface material and the soil in the adjacent drainage ditches; the life expectancy and standard of road; periods of use (seasonal or all-weather use); and road surfacing material as it relates to traction, types of vehicles and traffic, and traffic volume. Apply other grade restrictions in special situations. For example:

- On horizontal curves sharper than 80 m radius, reduce the adverse maximum grade by 0.5% for every 10 m reduction in radius.
- As required at bridge approaches, and at highway and railway crossings.

[c] S – sustained grade; P – short pitch

[d] Design maximum short-pitch favourable grades so that they are followed or preceded by a section of slack grade. The average grade over this segment of the road should be less than the specified sustained maximum.

[e] Design maximum short-pitch adverse grades as momentum grades.

**Table 3.** Minimum subgrade widths for roads on curves, for pole and tri-axle trailer configurations, and for lowbed vehicles.

| Radius of Curve (m) | Pole and Tri-axle Trailer Configuration<br>Minimum Subgrade Width (m) | Lowbed Vehicles<br>Minimum Subgrade Width (m) |
|---|---|---|
| 180 | 4.0 | 4.3 |
| 90 | 4.5 | 5.3 |
| 60 | 5.0 | 5.8 |
| 45 | 5.0 | 6.0 |
| 35 | 5.5 | 6.5 |
| 25 | 6.0 | 7.5 |
| 20 | 7.0 | 8.0 |
| 15 | 8.0 | 9.0 |

**NOTES:**

- The subgrade widths in this table do not allow for the overhang of long logs or any slippage of the truck or trailer due to poor road conditions.
- Apply the widening to the inside of the curve unless the curve has a 60 m long taper section on each end. For widening on the inside, provide a minimum 10 m section on each end of the curve.
- For two-lane roads or turnouts, it is assumed that the second vehicle is a car or single-unit truck. Add 4.0 m for logging trailer configurations and 4.5 m for lowbed vehicles.
- Double-lane any blind curves or provide adequate traffic control devices.

**Table 4.** Recommended turnout widths, based on stabilized road widths.

| Stabilized Road Width[a] | Description | Turnout Width[b] (m) |
|---|---|---|
| 9+ | 2-lane off-highway | none |
| 8 | 2-lane on-highway | none |
| 6 | 1-lane off-highway | 10 |
| 5 | 1-lane on/off-highway | 8 to 10 |
| 4 | 1-lane on/off-highway | 8 |

[a] Where no road surfacing is used, the stabilized road width is the width of the road subgrade. Sufficient room should be left on the low side to accommodate debris.

[b] Turnout width includes stabilized road width.

## *Fill slope and cut slope angles*

Stable cut slopes, road fills, borrow pits, quarries, and waste areas should be designed and constructed in a manner that will not contribute directly or indirectly to slope failures or landslides over the expected design life. Table 5 provides general guidelines for cut and fill slope angles for use in forest road design.

### Fill slopes

The stability of a fill slope depends on several variables, including the forces that tend to cause instability (gravitational and water pressure forces), and the forces that tend to oppose instability (e.g., shear strength resistance of the soil or rock materials expressed as an internal friction angle or cohesion). The stability of an embankment fill can be increased several ways:

- Construct the side slopes of fill embankments at a gentle angle, and usually not steeper than the "angle of repose." The term "angle of repose" should be used in the context of loose, cohesionless soils only (e.g., non-plastic silt, sand, sand and gravel). Constructing flatter side slopes in all types of soil will reduce the gravitational forces that tend to cause slope instability. For a fill slope in cohesionless material, the angle of repose is about the same as the *minimum* value of that material's angle of internal friction. Steeper fill slopes are more likely to cause a road-induced slope failure or landslide than flatter fill slopes.
- Compact the fill materials to make them more dense and increase the shearing resistance of the soil. The angle of internal friction depends primarily on the relative density (loose versus dense), the particle shape (round versus angular), and the gradation (uniformly graded versus well graded). For relatively loose cohesionless soils, the minimum value of the angle of internal friction will range from about 27 degrees (2H : 1V) for rounded uniform soil grains to 37 degrees (1⅓ H : 1V) for angular, well-graded soil grains. For relatively dense cohesionless soils, the maximum value of the angle of internal friction will range from about 35 degrees (1½ H : 1V) for rounded uniform soil grains to 45 degrees (1H : 1V) for angular, well-graded soil grains.

  **Note:** Fill slopes that are constructed at or less than the angle of repose (minimum angle of internal friction) will not necessarily remain stable if partial or full saturation of the fill occurs. Such saturation can result from surface and subsurface water flows during spring melt or after heavy periods of rainfall.
- Where necessary, provide good drainage of the fill to reduce the build-up of water pressure forces along potential planes of sliding within the fill. Expect that poorly drained fill materials will be prone to a greater likelihood of slope failure or sloughing than well-drained fill materials. Additionally, the slopes of poorly drained fills at locations of significant

zones of ground water seepage may experience larger and greater frequency of slope failures or sloughing problems. The significance of observed seepage zones might dictate the application of special drainage measures to reduce the likelihood of slope failure during construction and the intensity of maintenance activities over the operating life of the road. As a general rule, without special drainage measures, the side slopes of poorly drained fills (e.g., fills composed of silty soils) should be constructed at angles that are flatter than the angle of repose to minimize the likelihood of slope failures.

## Cut slopes

The design of cut slopes should consider and address factors such as the desired performance of the cut slopes, types of cut slope materials, issues about overall terrain stability, engineering properties of soils, seepage conditions, construction methods, and maintenance. In general, cut slopes will remain stable at slightly steeper angles than fill slopes constructed from like soil materials. The reason for this is the undisturbed soil materials in a cut (1) are often in a denser state than similar type materials placed in a fill, and (2) may contain sources of cohesive strength that further increases the shearing resistance of the soil.

Cut slopes constructed at too flat an angle can be uneconomical in steep ground because of the large volumes of excavation. Steeper cut slopes may be more economical to construct in terms of reduced volumes of excavation. However, they can also be more costly from an operational standpoint because they require more road maintenance.

For most forest roads, cut slope angles are generally designed to favour steeper angles to reduce the length of cut slopes, to minimize visible site disturbance, and to reduce excavation costs, provided that a somewhat higher level of road maintenance and likelihood of slope destabilization is acceptable for the site.

In the latter case, prepare and implement a maintenance schedule that addresses the erosional processes acting on the exposed cut slope face (such as splash, sheet, rill, and gully erosion) and reduces the threat to drainage systems (as a result of cut bank slope failure redirecting ditchwater flows onto potentially unstable fill or natural slopes), user safety, and the environment.

It may be necessary to construct flatter cut and fill slopes, or to build retaining wall structures to support cut slopes or fill slopes, in cases where slope stability problems are expected to be difficult to manage with maintenance measures alone.

**Table 5.** General guidelines for cut and fill slope angles for use in forest road design.

| | Cut Slopes | | Fill Slopes | |
|---|---|---|---|---|
| | Examples of Material Types[a] | Suggested Cut Slope Angles[b] for Cut Bank Height < 6 m[c] | Examples of Material Types[a] | Suggested Fill Slope Angles[b] |
| Coarse-grained Soils[d] | Road cuts in loose to compact SANDS or SANDS and GRAVELS (not cemented and non-cohesive) | 1½ H : 1 V | Road fills composed predominantly of SANDS, or SANDS and GRAVELS, or drained **mixtures** of coarse-grained and fine-grained soils | 1½ H : 1 V |
| Fine-grained Soils | Road cuts in loose SILTS, or soft cohesive soils such as SILTY CLAYS or CLAYS (not consolidated and not cemented) | 1½H : 1V for lower cuts<br>to<br>2H : 1V for higher cuts | Road fills composed predominantly of SILTS or CLAYS[e] | 2H : 1V |
| | Road cuts in hard cohesive soils such as SILTY CLAYS or CLAYS (consolidated) | 1H : 1V or flatter | | |
| Dense Glacial Till / Cemented Sands and Gravels | Road cuts in dense to very dense GLACIAL TILL (i.e., basal till), or cemented SANDS or SANDS and GRAVELS | ¾H : 1V or flatter | See above for coarse-grained soils | See above for coarse-grained soils |
| Rock[f] | Road cuts in strong, good quality ROCK masses with no significant weaknesses | ¼H : 1V<br>to<br>vertical | Road fill composed predominantly of individually placed and locked together (not dumped) good quality angular blasted or ripped ROCK | 1H : 1V |
| | Road cuts in other ROCK types should be flatter to include any weaknesses from the effects of structural discontinuities in the rock mass, and other factors such as the strength of the rock material, and the spacing, aperture, roughness, filling, weathering, and orientation of discontinuities | ¼H : 1V<br>to<br>1¼H : 1V | Road fill composed predominantly of dumped angular ROCK or placed rounded ROCK | 1¼H : 1V<br>to<br>1½H : 1V |

**Notes for Table 5:**

[a] Not all material types in the soil groups are represented in the table.

[b] For the design of roads located in domestic watersheds, on sensitive terrain, or in other areas where transport of sediment or landslides may adversely affect resources, it may be necessary to use flatter cut and fill slope angles to reduce the hazard of erosion or failure of cut and fill slopes. During construction of roads, it may be necessary to build flatter slopes where the road prism exhibits signs of distress, such as, for example: (1) cracks or scarps within original ground above the top of cut slopes, in the road surface, or within the fill slope on the downslope side of the road; and (2) significant zones of ground water seepage such that localized failure of cut or fill slopes are expected. Alternatively, installation of retaining wall structures may be needed to reduce excavation, contain bank material, or prevent slope failure. The significance of observed seepage zones might dictate application of other special measures to reduce the likelihood of slope failure during construction and over the operating life of the road.

[c] Consider the need to obtain advice from a qualified registered professional for cut heights greater than 6 m. The advantages of steeper cuts may include: less area occupied by road; less excavated material; less sidecast; and shorter slope lengths exposed to erosion processes. The disadvantages of steeper cuts may include: increased difficulty to establish vegetation; increased chance of slope ravelling, tension crack development and slope failure; and increased road maintenance costs. The disadvantages of steeper cut slopes can be reduced if high banks are avoided.

[d] Erosion control may be particularly problematic for slopes composed of sand, silty sands, or silts. Consider the need for erosion protection measures for cut slopes, fill slopes, and ditches, such as revegetation, soil bioengineering and biotechnical slope stabilization techniques, rip rap, or other special slope treatments.

[e] If significant compaction of the road fills can be achieved, then fill slopes (of limited height) may be placed steeper than 2H : 1V.

[f] If potential problems are anticipated for rock slopes either during design, construction, maintenance, or deactivation, consult with a geotechnical engineer or other rock slope specialist. It may be necessary to address the need for special rock slope stabilization measures (e.g., rockfall catch ditch, wire mesh slope protection, shotcrete, rock bolts).

### *Clearing widths*

Clearing widths should be as narrow as possible, to minimize impacts on other resources, but wide enough to accommodate:

- the road prism
- user safety
- turnouts
- subgrade drainage
- subgrade stability
- waste areas and endhaul areas
- pits and quarries
- landings
- slash disposal
- equipment operation
- snow removal
- fencing and other structures
- standing timber root protection, especially on cut banks.

Organic debris, rock, or any other excess material that cannot be placed in the road prism and within the clearing width because of terrain stability or other factors should be moved to waste areas. Such areas should be of suitable size to accommodate the estimated volume of waste material and should be identified in the road design.

Clearing widths are calculated on a station-by-station basis as part of a geometric road design. In situations where geometric road design is not required, other methods can be used. For further details, see Chapter 3, "Road Construction" and clearing width tables in Appendix 5.

### *Culvert drainage design*

Refer to Chapter 4, "Road Drainage Construction," for guidance on culvert drainage design.

### *Other structures*

A professional engineer must take design responsibility for cattleguard fabrication, the construction or modification of retaining walls greater than 1.5 m high, and the design of other specialized structures that fall within the practice of a professional engineer.

## Suggestions for further reading

British Columbia Institute of Technology (BCIT). 1984. *Manual for Roads and Transportation*. Vol. 1 and 2. Burnaby, B.C.

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Chatwin, S.C., D.E. Howes, J.W. Schwab, and D.N. Swanston. 1994. A guide for management of landslide-prone terrain in the Pacific Northwest. Land Management Handbook No. 18. 2nd ed. B.C. Ministry of Forests, Victoria, B.C. 220 p.

Fell, R. and D. Hardford. 1997. *Landslide risk management. Landslide Risk Assessment: Proceedings of the International Workshop on Landslide Risk Assessment, Honolulu, Hawaii, February 19-21, 1997*. D.M. Cruden and R. Fell (editors). A.A. Balkema, Rotterdam, Brookfield, p.51-109.

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# 2. Design and Construction of Bridges and Stream Culverts

## Introduction

This chapter describes some of the activities and practices that precede and follow the construction of forest road bridges and stream culverts. These include:

- design requirements for bridges and stream culverts
- bridge and major culvert design responsibility
- site data and survey requirements for bridges and major culverts
- construction drawings and specifications for bridges, major culverts, and stream culverts on fish streams
- site data and survey requirements for culverts on non–fish-bearing streams
- estimating design discharge for streams
- statement of construction conformance and documentation.

The *Forest Service Bridge Design and Construction Manual* (B.C. Ministry of Forests 1999) provides further discussion on planning, design, and construction of forest road bridges.

Consistent with the Forest Road Regulation, in this chapter:

- "bridge" means a temporary or permanent structure carrying a road above a stream or other opening
- "culvert" means a transverse drain pipe or log structure covered with soil and lying below the road surface
- "cross-drain culvert" means a culvert used to carry ditchwater from one side of the road to the other
- "major culvert" means a stream culvert having a pipe diameter of 2000 mm or greater, or a maximum design discharge of 6 $m^3$/sec or greater
- "stream culvert" means a culvert used to carry stream flow in an ephemeral or perennial stream channel from one side of the road to the other.

Refer to Chapter 4, "Road Drainage Construction" for further information on forest road drainage systems including; temporary stream crossings, ditch construction and cross-drain culverts, log culvert design and construction, and ford design and construction.

## Design requirements for bridges and stream culverts

The design of bridges and stream culverts encompasses more than the design of structural components. A bridge or stream culvert design should consider the composition and interaction of all the components, as well as their relationship and impact to the users, road, and stream. A bridge comprises the superstructure, substructure, connections, vertical and horizontal alignment controls, approach road fills, and scour protection works. Similarly, a stream culvert comprises the culvert materials, compacted backfill, scour protection, and roadway. Bridge or stream culvert designs include, but are not limited to, consideration of:

- user safety
- site selection
- environmental integrity
- fish habitat and passage
- impact of proposed structure on stream during and after construction
- site revegetation requirements
- structure alignment and location (vertical and horizontal) relative to the road and stream channel
- complete structure combination (substructure, superstructure, connections, and scour protection)
- suitability of selected foundations for the specific site
- design flood development
- navigation (*Navigable Waters Act*)
- debris potential and passage
- scour protection
- design vehicle configuration for load and alignment
- design service life influence on selection of bridge type and composition
- construction layout, methodology, and timing
- economics.

## Bridge and major culvert design responsibility

Bridge designs should clearly identify who is taking overall design responsibility (whether a professional engineer, professional forester, or non-professional) for ensuring that all aspects of the design have been appropriately addressed. In addition, a person required to prepare a road layout and design must ensure that a professional engineer takes design responsibility for major culverts.

## *Non-professional and professional forester bridge design*

Subject to specified constraints, a role is recognized for non-professionals and professional foresters with considerable experience in designing and constructing shorter, single-span structures. These are non-complex, standard width, non-composite structures, with relatively straight road alignments. They are constructed with conventional materials, on simple abutment supports, founded on excavations in original ground or on a shallow ballast layer. A professional engineer should assume responsibility for design of longer spans, higher abutments, and more complex bridge structures.

### Bridge design limitations

Design by non-professionals is limited to single spans with a maximum of 6 m centre-to-centre of bearing. Professional foresters are limited to single-span bridges with 12 m centre-to-centre of bearing or less.

For non-professional design, rip rap should not be required, as all bridge components (including rip rap or scour protection) are located outside of the design flood wetted perimeter. Where any components infringe or potentially infringe on the design flood wetted perimeter, design flood forces on these components should be considered and this part of the design must be completed by a professional engineer.

The stream should be historically stable, in a well-defined channel, with erosion-resistant banks, which are not subject to erosion or shifting in flood flows, such as would be the case on an alluvial fan.

The bridge abutments must be constructed on or below original ground or on a shallow ballast layer. This shallow ballast layer is intended to act only as a levelling surface to provide full bearing.

Note that the bridge superstructure must be non-composite. A composite bridge is one where a deck and girders are intimately connected such that they act as a unit to support the design load. These complex structures require a greater level of technical knowledge with respect to design and installation. Other structures included in this category are those with components that do not act independently of each other, such as concrete slab or box girders with welded or grouted shear connectors, or structures requiring field welding during installation.

Note also that welding is influenced by many factors, including: welder training and experience, type of weld (such as: rectangular groove, flat, vertical overhead, fillet, butt), welding equipment, welding rods, welding rate, ambient temperature and moisture, materials being welded, and so on. It is not possible to fully gauge the adequacy of a weld through only visual inspection. Since many structures require field welds, anyone considering design and erection of welded structures should ensure that persons with adequate training and experience are involved and responsible for all aspects of weld design and welding procedures.

Where shop or field welding is required, designs should indicate the minimum qualifications required. Use of Canadian Welding Bureau (CWB) certified firms and qualified welders is recommended.

Abutment heights, from the foundation level to the top of the abutment on which the superstructure would bear, are limited to log cribs less than 4 m in height or sills or pads up to 1.5 m in height. For log cribs, the 4 m height limitation is measured from the bottom of abutment where it bears on the ground to the top of the bearing sill or bridge soffit (underside of bridge superstructure).

Abutments that are not log cribs are limited to 1.5 m in height. Sills and caps are transitions to connect the superstructure to the substructure. They are not considered part of the maximum allowable abutment height, provided the transition depth is not excessive (a maximum sill or cap height of 400 mm is suggested), and that the sills, caps, and the connections have been produced from design aids prepared by a professional engineer for use in the proposed configuration.

Note that abutment heights are not cumulative; for example, a 1.5 m abutment is not intended to be designed to bear on top of a log crib or its fill. Binwalls are not considered log crib equivalents. Binwall abutments are more complex, requiring bearing of sills or pads on significant compacted fill depths, and must be designed by a professional engineer.

Bridge designs by non-professionals and professional foresters must be prepared using structural details provided in drawings, tables, charts, and other design aids that have been prepared by a professional engineer. Each bridge or major culvert must have its own site-specific design. The bridge components (superstructure, substructure, connections) must all have been designed to be used in the specific combination and configuration shown in the design. Any design aids used should be referenced on the design drawings or attached documentation.

Where portable bridges are used, the structure must have been designed or structurally analyzed by a professional engineer. The design or analysis should demonstrate adequacy for the intended use. Once the structure has been reviewed and approved by a professional engineer, the structure may be reused at new sites without specific professional engineer review, provided that:

- a qualified inspector has inspected the bridge at the new site before any use and detects no damage or deterioration of the structure;

- the design loads to be carried should be equal to or lower than original design loads; and
- the bridge is suitable and has been specifically designed for the new site, and the superstructure has been fabricated and constructed in compliance with the Forest Road Regulation.

The professional engineer, professional forester, or person assuming responsibility must sign off on the design for the bridge or major culvert and becomes the designer of record.

## Site data and survey requirements for bridges and major culverts

The person assuming design responsibility for a bridge or major culvert requires site-specific information for the proposed crossing. A detailed site survey (see Appendix E, "Bridge and Major Culvert Site Plan Specifications" in the *Forest Service Bridge Design and Construction Manual*) is recommended for all bridges and major culverts. The survey information is used to produce site plan and profile drawings for planning, developing, and evaluating the crossing design. Direction for the type and quality of site information to be collected and the site survey to be completed should be obtained from the designer. Included should be:

- the riparian class for streams or lake classification
- the apparent high water elevation of the stream, based on visible evidence of recent flooding
- a description of the composition and size of stream bed materials
- a description of stream bank materials and stream stability
- cross-sections and a profile of the crossing
- the stream flow velocity and direction, if the flow may influence the size or layout of the structure
- a description of the soil profiles and foundation soil conditions, based on soil explorations appropriate to the level of risk
- presence (or absence) of bedrock, and depth to, bedrock
- a description of any evidence of stream debris or slope instability that could affect the crossing, based on upstream observations
- any existing improvements or resource values in the vicinity that may influence the size or layout of the structure.
- if there is an existing structure, location and dimensions of the structure, including roadway, abutment, superstructure, and stream information
- the date of the survey
- the locations and dimensions of any upstream structures, and a note about whether they are problem-free

- any other pertinent information: Is the site currently accessible by road? Are there road or bridge restrictions on load length or weight? How can these be overcome? If test drilling seems likely, how much work is required to get a drilling truck (usually not all-wheel drive) to the site?
- if equipment fording will be necessary for construction, information about possible ford locations and other considerations such as depth of stream at that point, bottom material, and access gradients

If a fish stream is involved, the *Fish-stream Crossing Guidebook* (B.C. Ministry of Forests 2002) should be consulted for additional site requirements.

## Construction drawings and specifications

General arrangement drawings are the outcome of the design process and show the location, composition, and arrangement of the proposed structure in relation to the crossing. Site plan and profile drawings are design aids from which a proposed design is developed; they are not general arrangement drawings.

A set of construction drawings consists of the general arrangement drawings supplemented with detailed superstructure and substructure drawings and other fabrication, material, and construction specifications. Shop drawings are prepared by material fabricators to detail, and in many cases complete the structural design of bridge structure components. These drawings will form part of the construction drawing set and should be retained as part of the as-built documentation. The complete construction drawing set should provide comprehensive details on the location, composition, arrangement, design parameters, and fabrication, materials, and construction specifications for the specific proposed structure and is intended to be an integral part of the planning process, completed before construction begins.

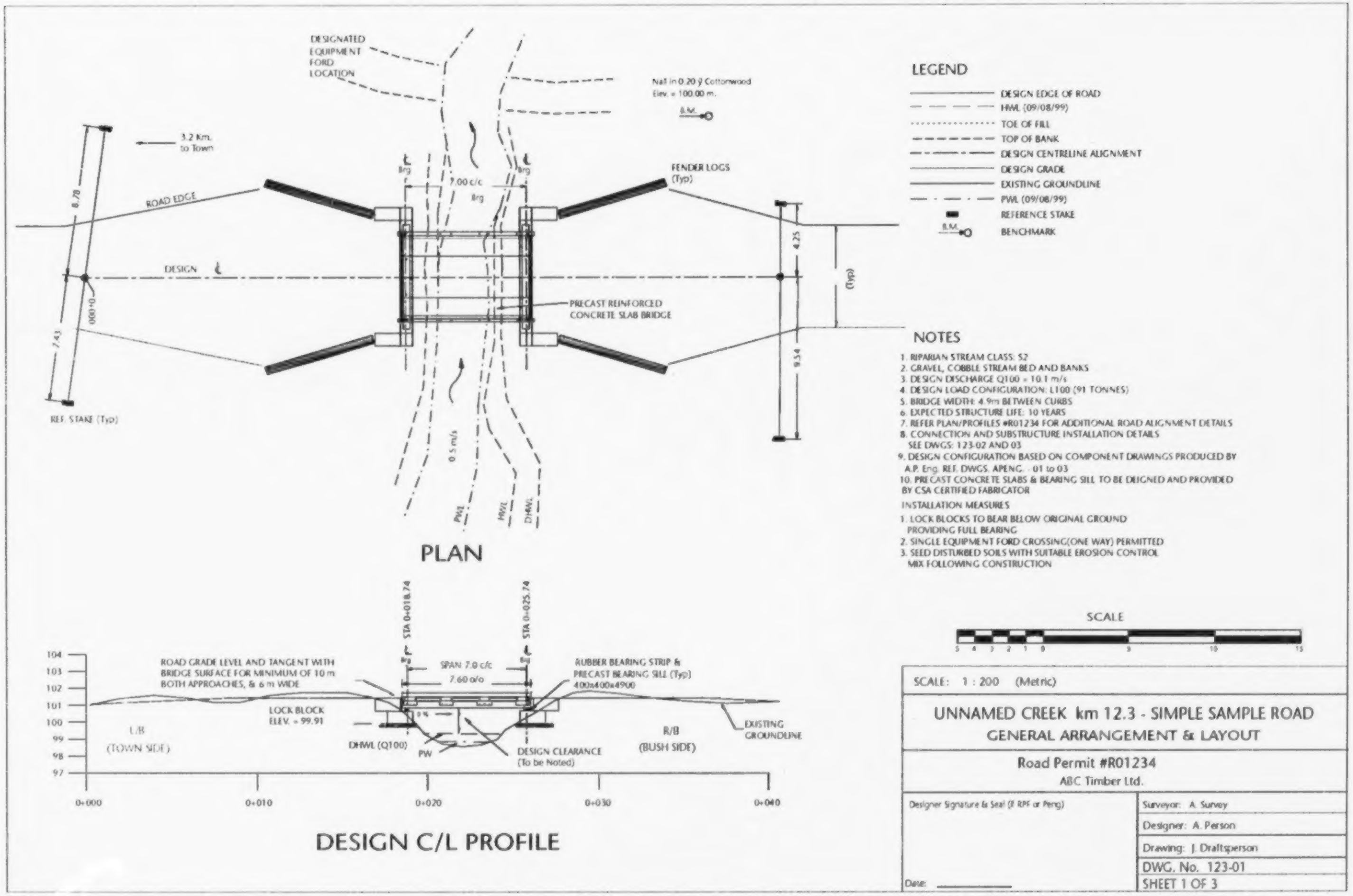
Typical scales for bridge and major culvert design and construction drawings are 1:200, 1:100, and 1:50. The construction drawings should clearly show all construction details and enable installation in general conformance with the design intent. Where appropriate, a smaller scale should be used for greater detail.

### *General bridge arrangement drawing requirements*

General arrangement drawings should clearly depict the proposed components and configuration of the bridge or major culvert in relation to the forest road, stream, and stream banks. These drawings may also be used during the agency referral process. Further details can be found in the *Forest Service Bridge Design and Construction Manual*.

Recommended contents for bridge and major culvert general arrangement drawings comprise:

- designer's name (and seal, if applicable)
- name of the stream, road, and station (km) and adequate information to detail the location of the structure
- design vehicle configuration for load and alignment
- design code references—specifically, those from the most recent version of the *Canadian Highway Bridge Design Code* and the *Canadian Foundation Engineering Manual*
- expected life of the structure in place (temporary or permanent)
- design high water elevation for bridges
- clearances between the design high water level and soffit (low point of underside of superstructure) of bridges
- details of debris passage or management strategies, if required
- road approaches, including width requirements (including allowance for vehicle side tracking) and side slopes, to a sufficient distance back from the bridge to show problems, or to the end of the first cut or fill
- dimensioning and labelling of component parts
- drawings scales
- relevant site plan and profile data; for suggested contents see above section on "Site data and survey requirements for bridges and major culverts" (sample general arrangement drawings are shown in Figures 4 and 5)
- location (vertical and horizontal) of proposed structure relative to field reference points
- possible ford locations
- special provisions related to the unique nature of the site and crossing, including specific instructions to bidders related to process or results, as appropriate
- references to specific design drawings or design aids used.


DESIGNATED EQUIPMENT FORD LOCATION
Nail in 0.20 ÿ Cottonwood
Elev. = 100.00 m.
B.M.
3.2 Km. to Town
ROAD EDGE
8.78
7.43
0+000
DESIGN ℄
REF. STAKE (Typ)
℄ Brg
7.00 c/c Brg
FENDER LOGS (Typ)
PRECAST REINFORCED CONCRETE SLAB BRIDGE
4.25
9.54
(Typ)
0.5 m/s
PWL
HWL
DHWL
PLAN
LEGEND
DESIGN EDGE OF ROAD
HWL (09/08/99)
TOE OF FILL
TOP OF BANK
DESIGN CENTRELINE ALIGNMENT
DESIGN GRADE
EXISTING GROUNDLINE
PWL (09/08/99)
REFERENCE STAKE
B.M. BENCHMARK
STA 0+018.74
STA 0+025.74
SPAN 7.0 c/c
7.60 o/o
ROAD GRADE LEVEL AND TANGENT WITH BRIDGE SURFACE FOR MINIMUM OF 10 m BOTH APPROACHES, & 6 m WIDE
RUBBER BEARING STRIP & PRECAST BEARING SILL (Typ) 400x400x4900
LOCK BLOCK ELEV. = 99.91
L/B (TOWN SIDE)
R/B (BUSH SIDE)
DHWL (Q100)
PW
DESIGN CLEARANCE (To be Noted)
EXISTING GROUNDLINE
104
103
102
101
100
99
98
97
0+000
0+010
0+020
0+030
0+040
DESIGN C/L PROFILE
SCALE
5 4 3 2 1 0 5 10 15

NOTES

1. RIPARIAN STREAM CLASS: S2
2. GRAVEL, COBBLE STREAM BED AND BANKS
3. DESIGN DISCHARGE Q100 = 10.1 m/s
4. DESIGN LOAD CONFIGURATION: L100 (91 TONNES)
5. BRIDGE WIDTH: 4.9m BETWEEN CURBS
6. EXPECTED STRUCTURE LIFE: 10 YEARS
7. REFER PLAN/PROFILES #R01234 FOR ADDITIONAL ROAD ALIGNMENT DETAILS
8. CONNECTION AND SUBSTRUCTURE INSTALLATION DETAILS SEE DWGS: 123-02 AND 03
9. DESIGN CONFIGURATION BASED ON COMPONENT DRAWINGS PRODUCED BY A.P. Eng. REF. DWGS. APENG. - 01 to 03
10. PRECAST CONCRETE SLABS & BEARING SILL TO BE DEIGNED AND PROVIDED BY CSA CERTIFIED FABRICATOR

INSTALLATION MEASURES

1. LOCK BLOCKS TO BEAR BELOW ORIGINAL GROUND PROVIDING FULL BEARING
2. SINGLE EQUIPMENT FORD CROSSING(ONE WAY) PERMITTED
3. SEED DISTURBED SOILS WITH SUITABLE EROSION CONTROL MIX FOLLOWING CONSTRUCTION

SCALE: 1 : 200 (Metric)

UNNAMED CREEK km 12.3 - SIMPLE SAMPLE ROAD
GENERAL ARRANGEMENT & LAYOUT

Road Permit #R01234
ABC Timber Ltd.

Designer Signature & Seal (If RPF or Peng)
Date: ______

Surveyor: A. Survey
Designer: A. Person
Drawing: J. Draftsperson
DWG. No. 123-01
SHEET 1 OF 3

**Figure 4.** Sample of general arrangement and layout (simple creek crossing).

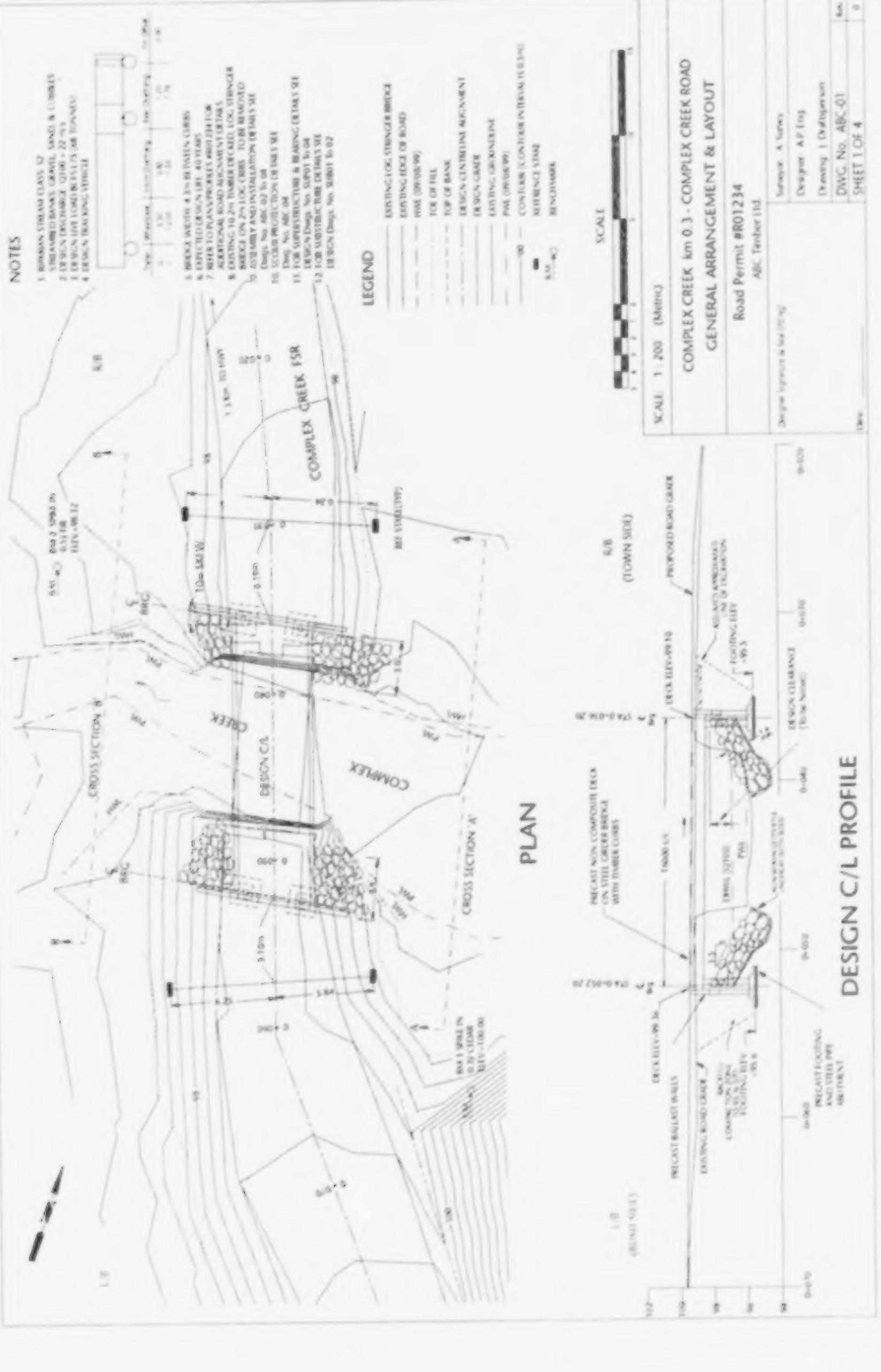

NOTES
LEGEND
SCALE
SCALE 1:200 (Metric)
COMPLEX CREEK km 0.3 - COMPLEX CREEK ROAD
GENERAL ARRANGEMENT & LAYOUT
Road Permit #R01234
ABC Timber Ltd.
DWG. No. ABC-01
SHEET 1 OF 4
COMPLEX CREEK FSR
COMPLEX
CREEK
DESIGN C/L
CROSS SECTION 'A'
CROSS SECTION 'B'
PLAN
DESIGN C/L PROFILE
R/B
(TOWN SIDE)
L/B

**Figure 5.** Sample of general arrangement and layout (complex creek crossing).

### Bridge superstructure drawing requirements

In addition to the general drawing requirements, the following elements should be detailed on bridge superstructure drawings:

- design code references—specifically, those in the latest edition of the *Canadian Highway Bridge Design Code* and the *Canadian Foundation Engineering Manual*
- materials specifications and CSA references, including but not limited to:
  - steel grades, impact category, finish
  - timber species, grades, preservative treatment
  - concrete strength, slump, and air entrainment
  - rip rap and geosynthetics
  - bearing materials and connections
- superstructure elements, configuration, and connections
- dimensions and sizes of components
- girder or stringer arrangements and connections
- span lengths
- bridge and road width
- deck elevations at bridge ends
- road and bridge grades and alignment
- deck configuration, connections, and component elements
- curb and rail configuration, connections, and component elements
- field fabrication details.

### Bridge substructure drawing requirements

The following information on foundation requirements should be detailed on the bridge substructure drawings:

- abutment elements, configuration, and connections
- dimensions and sizes of components
- critical elevations of substructure components
- scour protection: dimensions, composition, extent of placement, design slope, and other considerations
- piers
- location and sizes of piles or posts
- pile driving specifications, minimum expected pile penetrations, set criteria, and required service level capacities
- bracing and sheathing configurations.

### *Log bridge superstructure on log crib drawing requirements*

Since log stringer and crib materials are variable in nature and finished dimensions are not uniform, log bridge drawings will be somewhat schematic. Drawings should address layout, required component sizing, and connection details.

The following should be indicated on the log bridge superstructure and log crib drawings:

- schematic layout indicating width and span
- reference source for stringer and needle beam sizing
- minimum stringer, curb, and needle beam dimensions
- stringer, curb, needle beam, and crib logs specifications, including species, quality characteristics of acceptable logs, and seasoning
- stringer to cap bearing details, including shim types and stringer and cap bearing width and surface preparation
- dap details at log connections
- needle beam locations and connection details, if applicable
- space to add stringer, curb, and needle beam sizes as part of the as-built record
- deck layout, indicating tie sizes and spacing, plank thickness, and connections
- other materials specifications, including sawn timber, hardware, and shims
- excavated depth relative to scour line for mudsill or bottom bearing log
- general layout and arrangement of front, wing wall, deadman, and tieback logs, and their connections to each other and to the bearing log or cap
- description of crib fill material
- layout and description of in-stream protection, if applicable
- rip rap protection layout and specifications (as required).

### *Major culvert and fish stream culvert drawing requirements*

Drawings and notes for major culverts, and for stream culverts not classified as major culverts and installed on fish-bearing streams, should portray and describe the following:

- site plan (see previous section on "Site data and survey requirements for bridges and major culverts")
- location of the culvert, such as a key map
- design vehicle load

- fill height, depth of cover, and maximum and minimum cover requirements
- design slopes of fill and rip rap
- culvert invert elevations at the inlet and outlet
- culvert specifications and dimensions—opening dimensions, length, corrugation profile, gauge, and material type
- site preparation requirements
- embedment requirements, including a description of the substrate and any rock used to anchor the bed material in the pipe
- backfill and installation specifications
- installation camber
- culvert slope
- special attachments or modifications
- inlet requirements (rip rap layout, stilling basin, etc.)
- outlet requirements (rip rap layout, stilling basin, backwater weir for fish passage)
- rip rap specifications, including dimensions and configuration
- design high water elevation and design discharge
- connection details for pipe sections
- any existing improvements and resource values in the vicinity of the culvert that would influence or be influenced by the structure.

Any of the foregoing requirements can be combined. For example, drawings for a log stringer bridge on timber piles can include the details from "Log bridge superstructure on log crib drawing requirements," plus those from "Bridge substructure drawing requirements."

Any additional requirements for a fish stream culvert should be included as specified in the *Fish-stream Crossing Guidebook*.

## Culverts on non–fish-bearing streams

A detailed site plan is usually not required for stream culverts not classified as major culverts or those installed on non–fish-bearing streams. However, a minimum amount of information should be recorded during the road location survey to assist in sizing such a stream culvert for the 100-year flood return. Where conditions are such that there are complex horizontal and vertical or other control issues requiring higher-level design and installation procedures, detailed site plans are recommended.

In planning the layout of the structure:

- Choose an appropriate location, along a stream reach with uniform or uniformly varying flow close to the proposed crossing, to measure a cross-section. Sketch the cross-section of the stream gully, showing evidence of the high water level, present water level, and the depth of the stream across the bottom. The cross-section should extend back from the stream an appropriate distance to show the terrain that affects the proposed crossing and road alignment.
- Note any visual evidence of high water.
- Measure and record the average gradient of the stream at the crossing and at the cross-section if the two are taken at different locations.
- Record the soil type, soil profile, parent material, and substrate material at the crossing and describe the stream bottom.
- Describe the stream channel (debris loading, bank stability, crossing location on a fan, bedload problem, etc.).

If the site is a fish stream or a potential fish stream, the *Fish-stream Crossing Guidebook* should be consulted for site and design requirements.

## Estimating design discharge for streams

The following guidelines apply to determining the design discharge for streams for a particular recurrence interval. Establishing a return period provides a benchmark of the relative risk to be attached to any particular design.

These guidelines should not preclude use of other reasonable and accepted methods for determining the design discharge. Professional engineers, who in the course of carrying out their professional functions as designers of a bridge or a major culvert (2000 mm or greater in diameter or with discharges of 6 $m^3$/sec or greater), are ultimately responsible for establishing the design discharge for that structure. Others determining stream discharges should be familiar with methods and their limitations, or consult those with training and experience in stream discharge determination.

### *Factors affecting runoff*

The runoff and behaviour of a stream depends on many factors, most of which are not readily available or calculable, such as:

- rainfall (cloudbursts; hourly and daily maxima)
- snowpack depth and distribution, and snowmelt
- contributory watershed area, shape, and slope
- topography and aspect
- ground cover

- soil and subsoil
- weather conditions
- harvesting and road or other upslope development
- drainage pattern (stream order, branchiness; lakes and swamps)
- stream channel shape, length, cross-section, slope, and "roughness."

Because topography, soil, and climate combine in infinite variety, drainage for specific sites should be designed individually from available data for each site. In addition, the designer should consult those who have long experience in maintaining drainage structures in the area.

## Some methodologies to estimate design flood discharge

There are too many analytical and empirical methods for estimating stream discharge to be discussed at any length in this guidebook. Methodologies commonly used involve:

- working from available evidence of flood flows in the specific stream;
- gathering evidence of flood flows in other streams, relating these to their drainage basin characteristics, and then, from the characteristics of the basin under consideration, estimating a flood flow; or
- relating meteorological data to stream basin characteristics and estimating flood flow through empirical methods.

The necessary data for these methodologies can be obtained from several sources:

**Site information:** Site data at and adjacent to the proposed crossing can be used to determine the maximum flow. Records of culverts and bridges within the vicinity that have successfully withstood known flood events can be used to develop flood flows.

**Stream basin characteristics:** Stream basin characteristics such as length, slope, order, roughness, vegetative characteristics, and elevation band, combined with meteorological data, can be used in empirical approaches to determine design flood flows.

**Data on other streams:** Studies done on other streams in the vicinity, with similar characteristics, can provide relationships and comparative values.

**Hydrometric records:** The Water Survey of Canada provides, in its Surface Water Data, annual reports of readings on hydrometric stations throughout the province. In addition, it publishes Historical Stream Flow Summaries in which mean values and annual peaks are tabulated. These stream flow records can be used to project design flood flows from theoretical analysis.

### Comparing discharges using hydrological information

Determining design flood discharge usually involves applying several different methods and then using judgement to select an appropriate design value. In all stream flood discharge determinations, it is prudent to compare the proposed opening size with historically problem-free existing stream crossings serving similar drainages in the same area.

The designer should compare the flood discharge estimates derived from the site information with other data and theoretical derivations. The final selection of design discharge and resulting bridge opening or major culvert size should then be based on the designer's judgement, taking into account these comparisons, together with consideration of debris potential, ice jams, or other local factors that might influence the structure opening.

### High water estimation method for stream culverts

Application of this method for determining the $Q_{100}$ from site information should be limited to non-major stream culverts—less than 2000 mm in diameter or less than 6 $m^3/s$ design discharge. It is not appropriate for use as the sole method for "professional" designs.

This method assumes that the high water width represents the mean annual flood cross-sectional flow area for the stream ($Q_2$); and that the $Q_{100}$ cross-sectional flow area is three times this. It also assumes that the discharge is not sensitive to influences from pipe slope, roughness, or other factors. These assumptions are not truly representative of all situations, but, within the accuracy expected for establishing design discharge, should be acceptable for sizing stream culverts smaller than 2000 mm diameter or 6 $m^3/s$ on forest roads.

The high water width is defined as the horizontal distance between the stream banks on opposite sides of the stream, measured at right angles to the general orientation of the banks. The point on each bank from which width is measured is usually indicated by a definite change in vegetation and sediment texture. Above this border, the soils and terrestrial plants appear undisturbed by recent stream erosion. Below this border, the banks typically show signs of both scouring and sediment deposition. The high water width should be determined from recent visible high-water mark indicators, which would approximate the mean annual flood cross-section. This point is not necessarily the top of bank, particularly in the case of an incised stream.

- Locate a relatively uniform stream reach in close proximity to the proposed culvert location. Note that this not an averaging process that would be used for determining the stream channel width for the purpose of assessing stream habitat impacts. A uniform stream reach would have a consistent cross-section, bed materials, and channel slope. It would also be relatively straight.

- Estimate the visible high water stream width and cross-sectional area.
  - a) Measure (in metres) the high water width at a relatively uniform reach of the stream, representative of the mean annual flood ($W_1$) and at the stream bottom ($W_2$) (see Figure 6).
  - b) Measure the depth of the stream at several spots across the opening to obtain the average depth (D) in metres.
  - c) Calculate the cross-sectional area of the stream, $A = (W_1 + W_2)/2 \times D$.
- Calculate the area of the required culvert opening, $A_c = A \times 3.0$.
- Size the pipe (see Table 6), using the smallest pipe area that exceeds the required area, or select an opening size for a log culvert that will be greater than $A_c$.

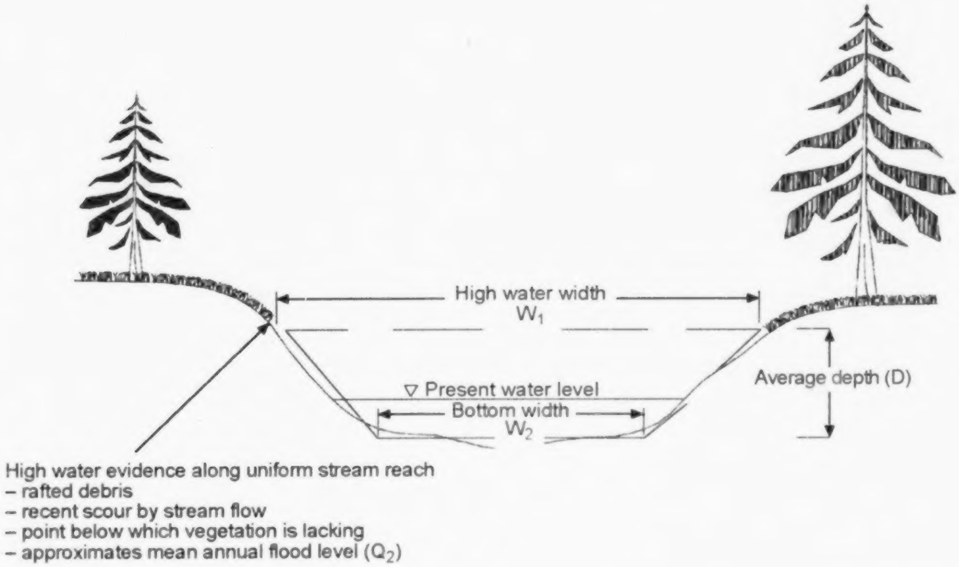
The high water width method can be cross-checked if field or other evidence of an approximate 10-year flood is available. In this case, the area of the $Q_{10}$ flood can be multiplied by 2 to estimate the minimum culvert area for the $Q_{100}$ flood.

## Example

If $W_1 = 1.2$ m
$W_2 = 0.8$ m
$D = 0.5$ m
stream cross-sectional area $A = 0.5$ m$^2$

Then $A_c = 0.5 \times 3.0 = 1.5$ m$^2$

Therefore (from Table 6), the required pipe culvert size = 1400 mm.


High water width
$W_1$
Average depth (D)
▽ Present water level
Bottom width
$W_2$
High water evidence along uniform stream reach
– rafted debris
– recent scour by stream flow
– point below which vegetation is lacking
– approximates mean annual flood level ($Q_2$)

$$\text{High water width cross-sectional area} = \frac{(W_1 + W_2)}{2} \times D$$

**Figure 6.** High water width cross-sectional area.

**Table 6.** Round pipe culvert area ($A_c$) versus pipe diameter.

| $A_c$ ($m^2$) | Pipe Diameter (mm) |
|---|---|
| 0.13 | 400 |
| 0.20 | 500 |
| 0.28 | 600 |
| 0.50 | 800 |
| 0.64 | 900 |
| 0.79 | 1000 |
| 1.13 | 1200 |
| 1.54 | 1400 |
| 2.01 | 1600 |
| 2.54 | 1800 |

## General conformance and construction documentation

After construction of a bridge, major culvert, stream culvert, or other specialized structure, the person responsible (non-professional, professional forester, or professional engineer) must sign (and seal, as appropriate) a statement indicating that the entire structure is in general conformance with the design drawings and specifications.

Where a professional forester has taken design responsibility for a bridge, a professional forester or a professional engineer must provide a signed and sealed statement that the bridge is in general conformance with the design drawings and specifications.

Where a professional engineer has taken design responsibility for a bridge, a professional engineer must provide a signed and sealed statement that the bridge is in general conformance with the design drawings and specifications.

A sample statement of construction conformance is located in Appendix 4.

Documentation of materials used, and as-built records for the bridge or major culvert, should be obtained during fabrication and construction. The person responsible for construction should obtain and retain as-built records, including:

- any pile driving records, hammer type, penetration, set criteria, etc.
- fabrication plant inspection reports, including mill test certificates, concrete test results, etc.
- shop or as-built fabrication drawings
- concrete and grout test results
- field compaction results
- other pertinent fabrication, field, and construction data.

As-built drawings are the "approved for construction" drawings—which may be the approved design drawings—marked up to show all significant variations from the original design. For example, mark-ups would show as constructed details such as precise location in plan, finished pile depths, footing elevations, deck and other finished elevations, finished dimensions, and configurations of components. The as-built drawings should be signed (and sealed, where applicable) by the individual taking responsibility for the as-constructed structure being in general conformance with the design. Where the original design has been modified, these drawings should have been amended by the designer, before inserting the as-built notes and details.

The as-built drawings, materials records, fabrication documentation, and other field and construction documentation must be retained for the life of the structure.

## Suggestions for further reading

American Iron and Steel Institute. 1984 (3rd Printing, May 1995). *Handbook of Steel Drainage & Highway Construction Products*. Canadian Edition. New York, N.Y.

British Columbia Ministry of Forests. 2002. *Fish-stream Crossing Guidebook*. Victoria, B.C.

____________. 1981. *Log Bridge Stringers and Needle Beam Sizing* (Metric Edition). Victoria, B.C.

____________. 1999. *Forest Service Bridge Design and Construction Manual*. Victoria, B.C.

Canadian Geotechnical Society. 1992. *Canadian Foundation Engineering Manual*. Richmond, B.C.

Canadian Standards Association. 2001. *Canadian Highway Bridge Design Code, CAN/CSA-S6*. Toronto, Ont.

Transportation Association of Canada. 2001. *Guide to Bridge Hydraulics*. 2nd edition. Ottawa, Ont.

Wellburn, G.V., M.M. Nagy, and J.T. Trebett. 1980. *Log Bridge Construction Handbook*. Forest Engineering Research Institute of Canada, Vancouver, B.C.

# 3. Road Construction

## Introduction

The purpose of this chapter is to assist practitioners in meeting forest road construction and modification requirements under the Forest Practices Code. Successful construction involves building roads that are appropriate for the expected service life (see Chapter 1, "Road Layout and Design") while minimizing adverse impacts on other forest and non-forest resources.

Since road construction activities can have adverse impacts on fisheries resources, particular care must be exercised when work is under way near riparian management areas and at stream crossings. Timing construction to use instream work windows, and scheduling operations so that construction is carried out without undue delay, will help to minimize these impacts.

The following topics are covered in this chapter:

- road corridor preparation activities during removal of timber from the corridor, including establishing and laying out clearing widths, establishing pilot trails, and felling and yarding within the clearing width
- grubbing and stripping operations within the road corridor and disposal of slash and debris
- subgrade construction activities, including:
  - construction surveys, and methods to make modifications to the road layout and design
  - sidecast and full bench construction techniques
  - endhauling practices, example swell factors to convert from bank volumes to loose volumes, and drilling and blasting
  - overlanding techniques for construction in swampy terrain, borrow pit locations, and winter construction of permanent roads
  - protecting erodible fills located within floodplains
  - requirements for the use, storage, and disposal of litter, petroleum products, and other waste products.
- stabilizing the road subgrade and surfacing the road to support traffic loading
- construction and use of snow and one-season winter roads, and construction of 5-year roads
- surface erosion and sediment control techniques
- road works shutdown indicators and procedures.

# Road corridor preparation

## *Establishing clearing widths*

Clearing widths are established to facilitate the construction, use, and maintenance of forest roads. The objective is to minimize the width of the clearing, yet accommodate:

- 1–3 m of width between standing timber and any excavation to avoid undercutting roots that may create dangerous trees and destabilize the top of road cut (see Figures 7 and 8)
- the road prism, including widenings for curves and turnouts
- subgrade drainage structures
- landings and slash disposal without piling wood or excavated material against standing trees
- borrow pits, gravel pits, quarries, and waste areas
- safe sight distance for user safety
- snow removal
- fencing and other structures that are ancillary to the road
- other special operational requirements.

For natural slopes up to 60%, clearing widths can be conveniently determined from the tables in Appendix 5. For slopes greater than 60%, or in areas of moderate or high likelihood of landslides, clearing widths should be determined from the geometric road design.

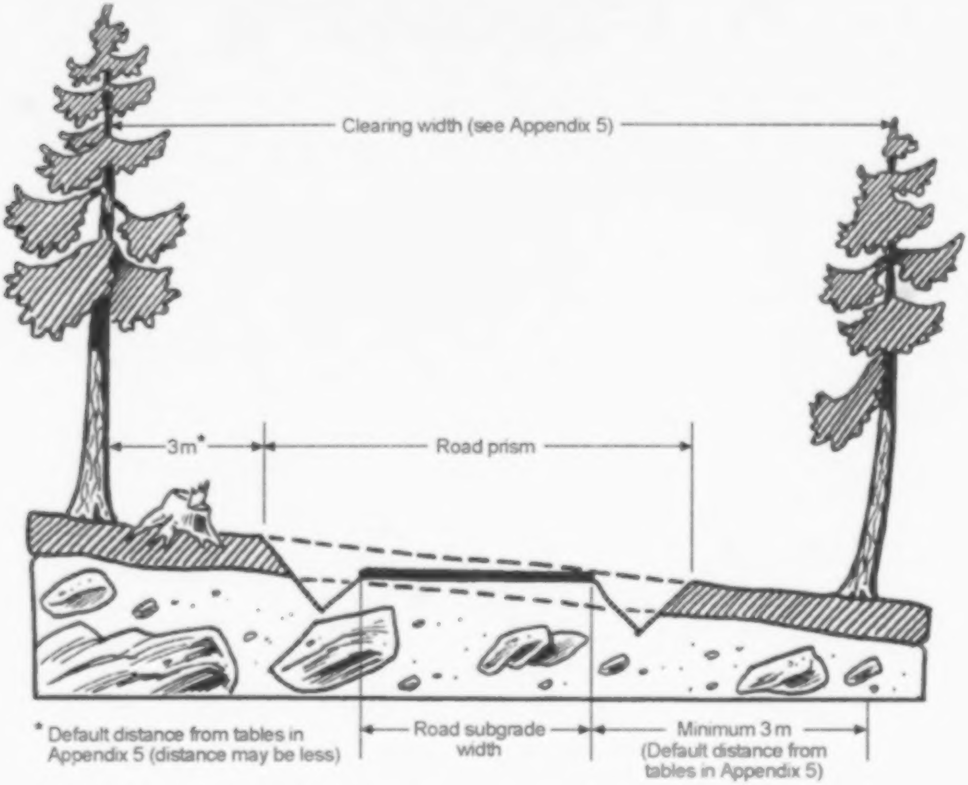

Clearing width (see Appendix 5)
3m*
Road prism
* Default distance from tables in Appendix 5 (distance may be less)
Road subgrade width
Minimum 3 m
(Default distance from tables in Appendix 5)

**Figure 7.** Typical roadway on gentle slopes with no additional clearing.

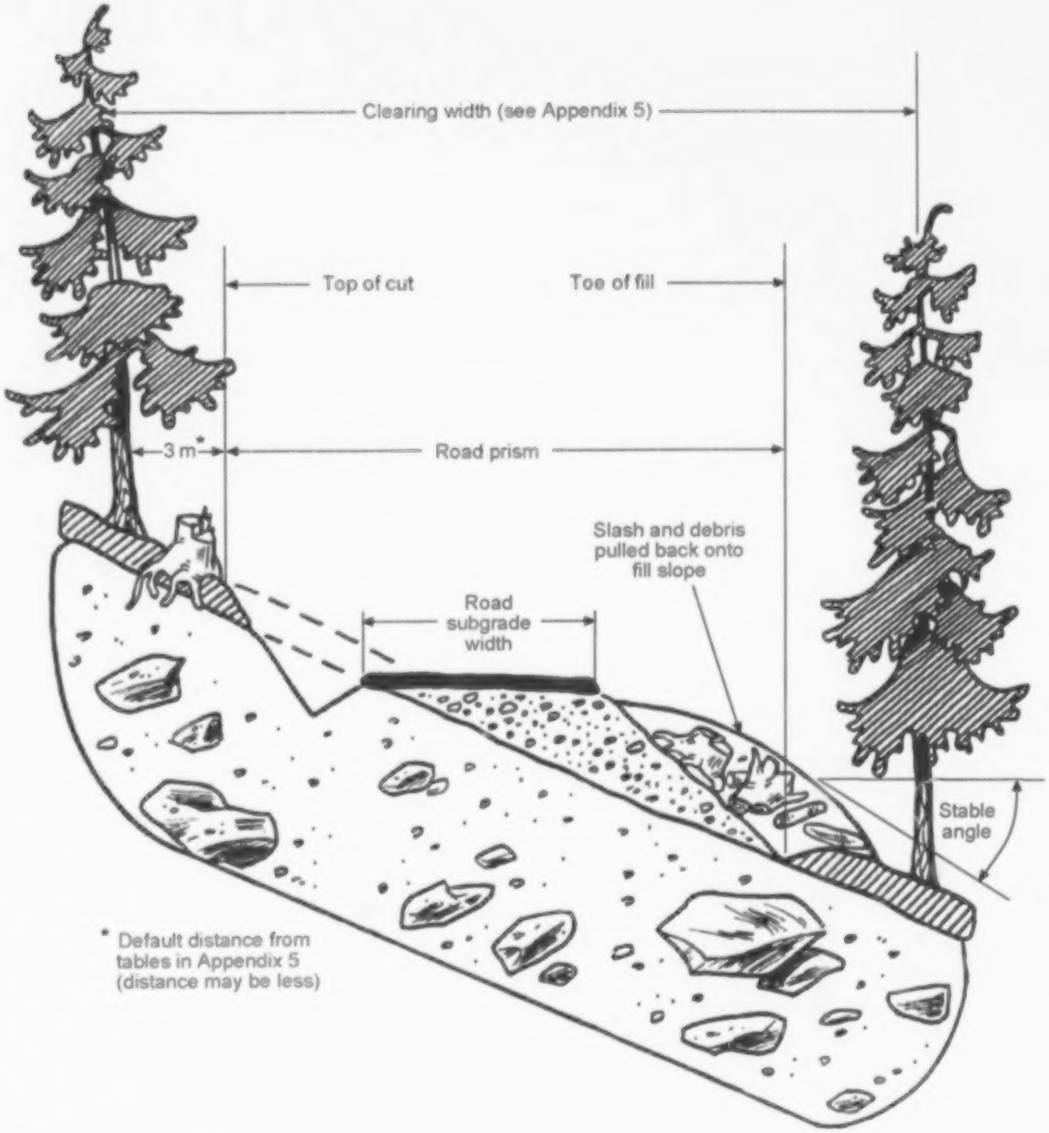

Clearing width (see Appendix 5)
Top of cut
Toe of fill
3 m*
Road prism
Slash and debris pulled back onto fill slope
Road subgrade width
Stable angle
* Default distance from tables in Appendix 5 (distance may be less)

**Figure 8.** Typical permanent roadway on moderate slopes (best practice).

### *Laying out clearing widths*

Clearing limits should be marked in the field with flagging tape. The clearing boundaries should be sufficiently flagged to be clearly visible for machine operators or hand fallers to follow.

Flagging should be hung on trees and shrubs that will remain after the clearing operation is completed. Trees that are on the boundary should be left standing unless the roots will be undermined by operations within the clearing width. Where slope staking is not required, the flagging can be used as an offset line to establish the top of cut for grade construction.

### *Establishing pilot trails*

Frequently, pilot trails or tote roads are built within the clearing width before falling begins. These trails are to provide easy access for the faller (hand or mechanical), a route for skidding felled timber to a landing or collection point, and temporary access along the road corridor.

Terrain and soil conditions will govern the location of the pilot trail within the clearing width. Generally, the trail is constructed below the flagged centreline on side hills, near the lower clearing width limits. This allows for easy access to skid fallen timber, and allows for the toe of the road fill to be keyed into the slope. Where drilling for blasting is required, the trail may be built above the road centreline, just below the upper clearing limit, to permit vertical drilling of the rock cut.

Care should be taken during pilot trail construction to minimize damage to any timber and to ensure that unsafe conditions are not created for fallers. Excavators are superior machines for constructing trails because they can push down, remove, and place trees along the trail for easy removal later.

Pilot trails are often constructed to allow trucks to remove the merchantable timber within the clearing area. This is desirable where there is insufficient room to construct large landings for timber storage.

Drainage structures should be installed concurrently with pilot trail construction. Temporary stream crossings may be required during the road construction phase until the permanent crossing is commissioned. Ideally, to minimize the impact on the stream, the temporary crossing should be situated in the same location as the permanent crossing, but this may be impractical. For further details, see Chapter 4, "Road Drainage Construction."

## Felling and yarding within the clearing width

### Felling methods

Several methods for falling trees within the clearing width are available, depending on terrain, soil conditions, timber size, and total volume.

*Mechanical methods:*

- feller-bunchers (tracked, high flotation tired) used for merchantable and non-merchantable timber and on terrain suited to the safe operation of such equipment
- crawler tractors/excavators used for non-merchantable timber or to assist hand fallers where hang-ups or faller safety dictates such action.

*Hand methods:*

- hand falling to avoid site impacts associated with mechanical falling
- directional falling of leaning timber, using jacks, excavators, or hydraulic log loaders.

*Explosives:*

- use is restricted to falling large dangerous trees that cannot be removed safely by other means
- if used adjacent to streams, explosives must first be approved by the appropriate resource agencies
- the person using explosives must have a valid Workers' Compensation Board Blaster's Certificate.

Further information about falling is contained in the British Columbia Occupational Health & Safety Regulation and the Workers' Compensation Board of B.C. *Fallers' and Buckers' Handbook.*

### Techniques for protecting stream banks during felling operations

Before falling begins, ensure that streams and their associated riparian management areas and the "machine-free zones" identified on operational plans are flagged in the field, and use appropriate directional falling techniques to protect these areas.

Where felling timber across a stream is unavoidable, buck the tree carefully into shorter lengths and lift it out of the stream or off the stream banks. Avoid skidding the tree across the stream. For further information, refer to the *Riparian Management Area Guidebook.*

### Techniques for protecting stream banks during yarding operations

Stream bank destabilization resulting from yarding operations should be avoided. This is best accomplished by yarding away from streams, not across them. Options for avoiding stream bank damage include:

- using overhead systems or hydraulic log loaders or excavators to lift, not drag, the felled trees away from the stream
- where machines are used to lift trees away from the stream, minimizing equipment movement and removing any puncheon placed to support the machine as the machine moves
- using temporary crossings (skid bridges) or installing a permanent structure before yarding; refer to Chapter 4, "Road Drainage Construction" for more details on temporary stream crossings.

### Removing debris from streams

Where debris is accidentally introduced into the stream, clean-up should take place concurrently with clearing operations. Any stream bank damage, outside of designated crossings, should be reported to the appropriate resource agency immediately so that any mitigative prescriptions can be approved and carried out without delay.

### Dangerous trees

All dangerous trees outside the clearing width but deemed hazardous to road workers or users should be felled concurrently with the felling phase of site preparation.

## Grubbing and stripping

After all standing trees and dangerous trees have been felled and removed, the road prism should be grubbed and stripped of all topsoil and unsuitable mineral soils. Grubbing includes the removal of stumps, roots, logging slash, and downed or buried logs. Stripping includes the removal of topsoil, or other organic material, and mineral soils unsuitable for forming the road subgrade.

Where grubbing operations have removed all organic soil, no stripping is required unless other unsuitable soils are encountered.

Organic material, such as stumps, roots, logging slash, embedded logs, topsoil, and otherwise unsuitable soils may be left within the subgrade width where one-season winter use or snow roads are constructed, or where overlanding techniques are applied.

## Disposal of slash and debris

Slash and debris must be disposed of by burning, burying, scattering, or end-hauling. The method selected should:

- meet objectives of higher-level plans (such as those for smoke management, aesthetics, or pest management)
- be compatible with terrain conditions
- consider the slash volume, loading, species, and piece sizes
- not alter natural drainage patterns
- be compatible with other resource values.

Disposal sites must:

- be sufficiently stable to support the debris
- have very low potential for failing into a stream (such as by landslide or snowslide)
- have little or no impact on other forest resource values.

Under no circumstances may slash be placed within the high-water mark of a stream, or in a manner likely to cause the material to fall into a stream.

Best practice is to remove all organic debris from within the road prism width (Figure 8). However, where the road **does not** cross areas having a moderate or high likelihood of landslides as determined by a TSFA, stumps, roots, and embedded logs may be incorporated in the road prism as follows:

- stumps, roots, and embedded logs may be left or placed **outside the road subgrade width** on the downhill side (Figure 9)
- for a 5-year road (Figure 10), stumps, roots, and embedded logs may be left or placed **within the road subgrade width**. For more information about 5-year roads, refer to "Construction of 5-year roads" later in this chapter.

For each of these two situations above, the person responsible for constructing the road must provide a statement that indicates that leaving or placing stumps, roots, and embedded logs in the road prism will not significantly increase the risk of a failure of the road subgrade.

In all cases of road site preparation, topsoil must be removed from within the road prism width.

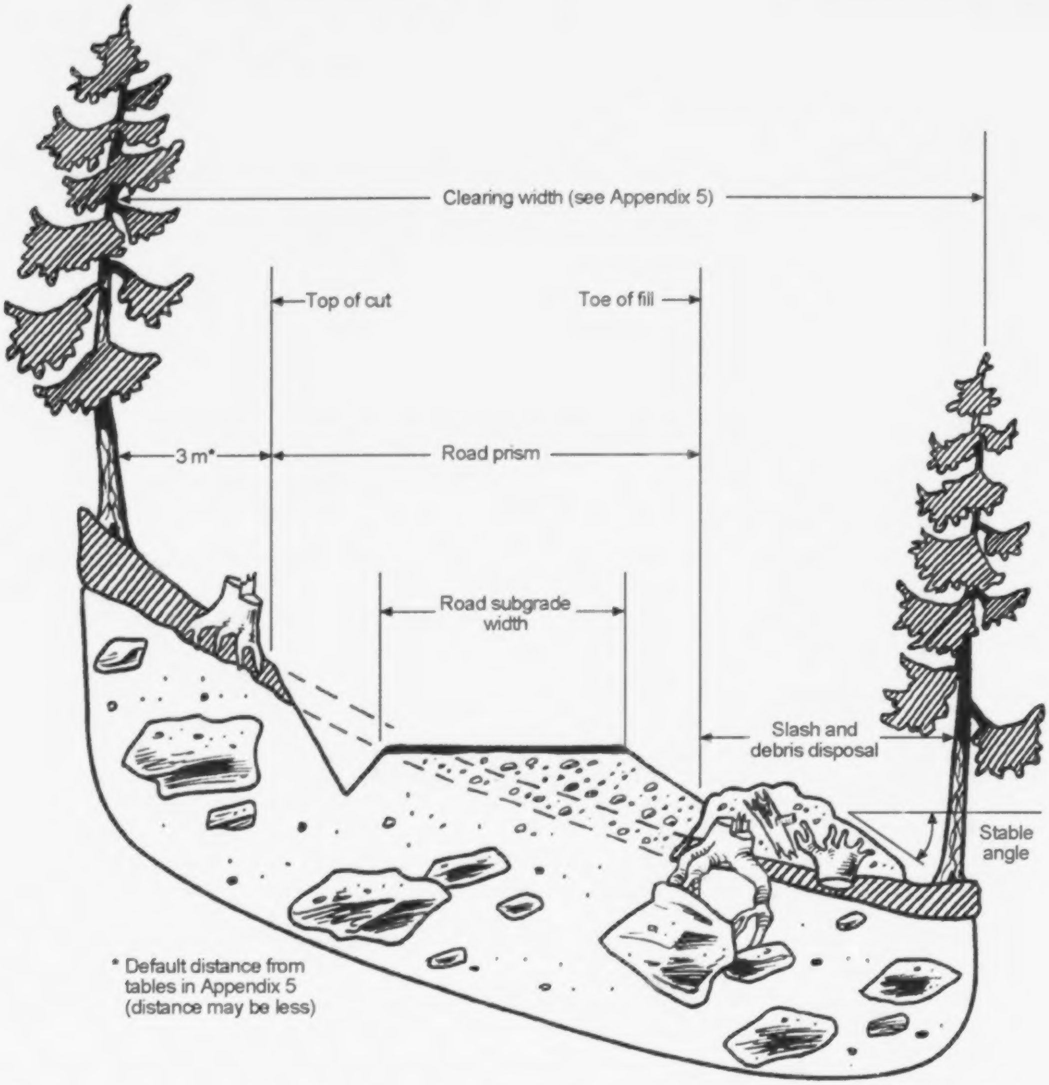

Clearing width (see Appendix 5)
Top of cut
Toe of fill
3 m*
Road prism
Road subgrade width
Slash and debris disposal
Stable angle
* Default distance from tables in Appendix 5 (distance may be less)

Figure 9. Permanent road in low likelihood of landslide terrain (acceptable practice).

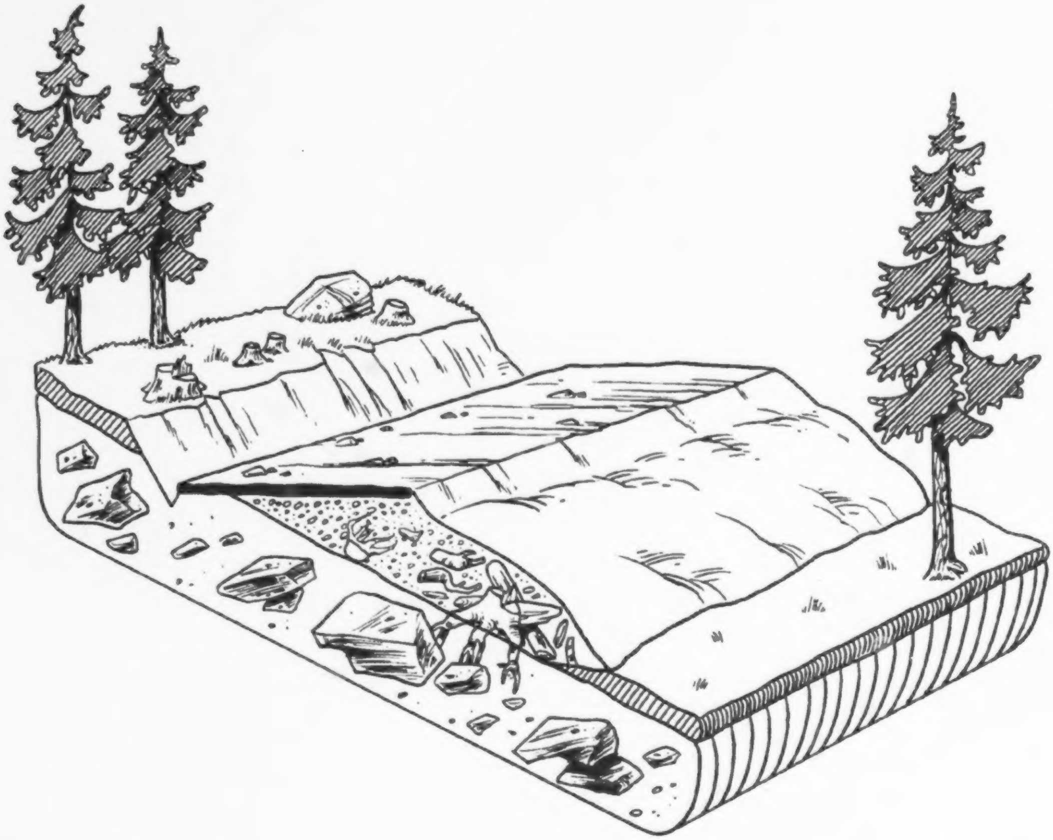


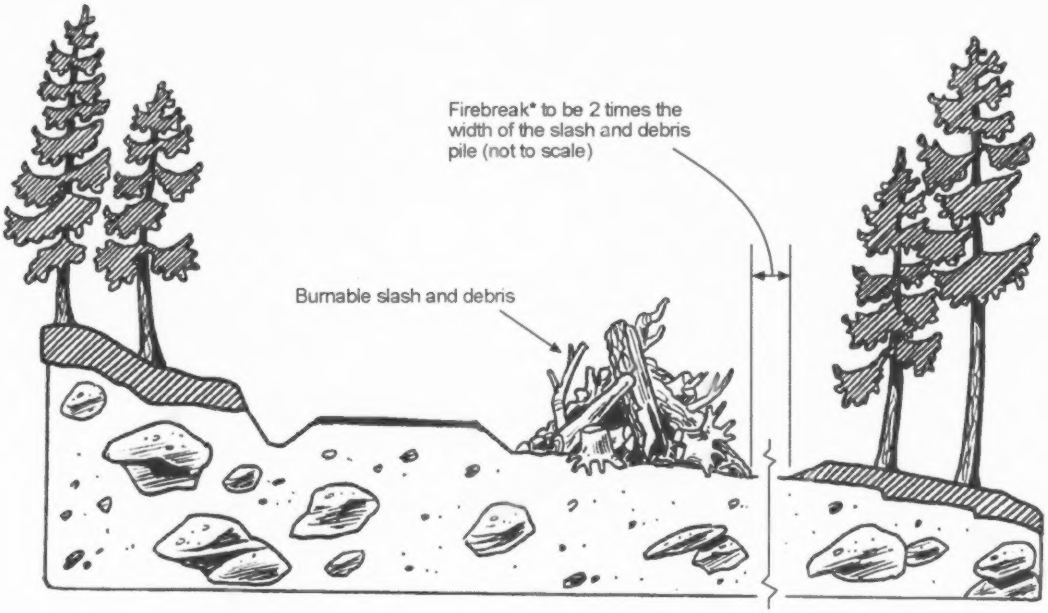
**Figure 10.** Typical 5-year road showing debris placement.

### Piling and burning

Piling and burning (Figure 11) may be considered as an alternative to burying in areas with flatter terrain, heavy slash loading, and moderate to high pest or fire hazard, and where smoke management objectives can be met. Where possible, use natural openings and landings.

- pile slash and debris at least twice the width of the pile away from standing timber
- to facilitate efficient burning, ensure that the slash pile contains as little soil as is possible
- ensure that slash is piled tightly, using a brush blade or excavator
- excavate a fireguard down to mineral soil around each burn pile to prevent ground fire escape
- ensure that a Burning Reference Number has been obtained before initiating the burn.

The use of burning racks can be very useful to ensure that a hot clean burn results. This eliminates the need to push in or re-pile debris that does not burn cleanly.


Firebreak* to be 2 times the width of the slash and debris pile (not to scale)
Burnable slash and debris

* Firebreak required by the Forest Fire Suppression and Prevention Regulation

**Figure 11.** Slash and debris disposal by piling and burning.

### Burying

Burying is usually the preferred practice and there are three methods for burying slash and debris with overburden material: trenching, mounding or windrowing, and creating pushouts.

The volume of slash and overburden should first be calculated per lineal metre of road. Generally, for every cubic metre of debris, a metre of clearing is required for disposal (Figure 12). When excessive slash volumes are encountered, other disposal methods should be considered.

Buried material should:

- be compacted before being covered with soil
- be covered with a minimum of 300 mm of soil
- be placed so as not to interfere with roadway or other drainage, utilities, planned road improvements, snow removal, design sight distance, future developments, or standing timber
- not interfere with any watercourse.

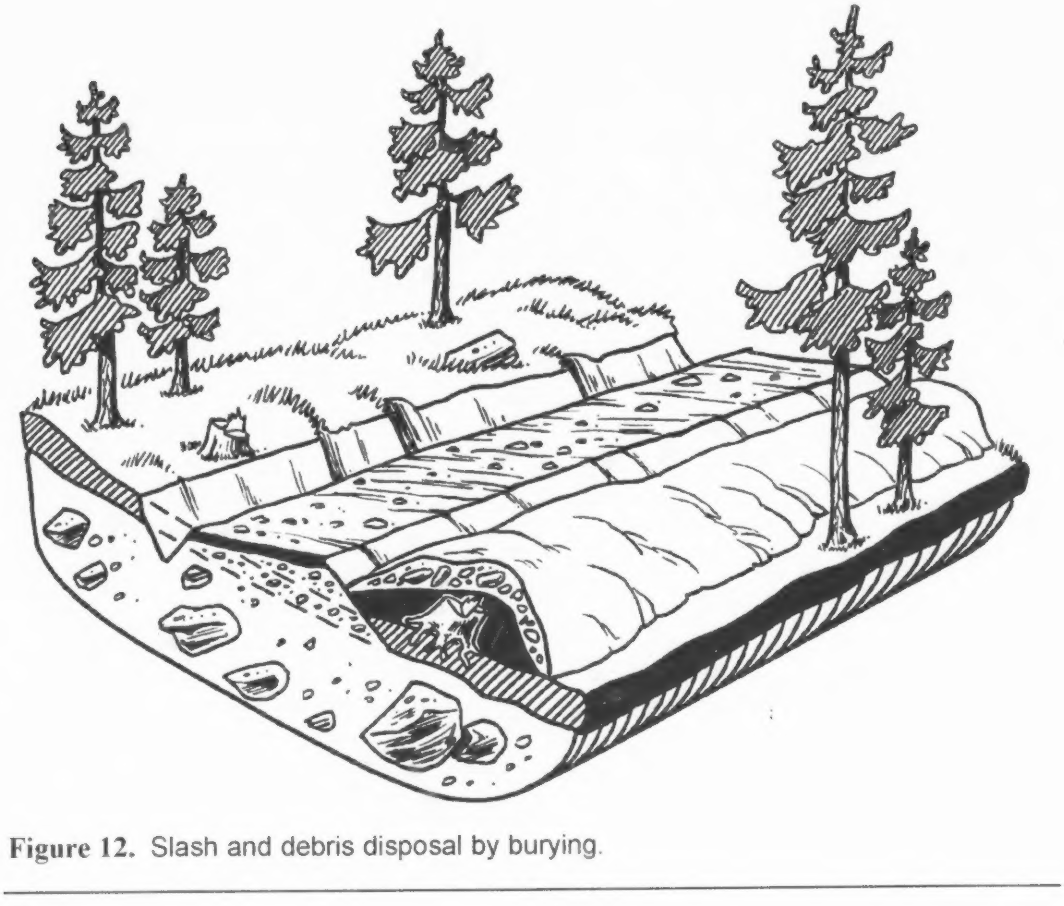


**Figure 12.** Slash and debris disposal by burying.

## Trenching

This is a type of burying in which slash and debris are placed in a trench rather than being spread over the ground surface. The volume of debris should determine the size of the trench. To minimize the size of the cleared area, a deep, narrow trench is preferable to a shallow, wide trench (Figure 13).

To prevent undermining tree roots, 3 m of cleared width should remain between any standing timber and the trench. The trench should lie parallel to the roadway and may be continuous or intermittent, depending on the volume of debris. The woody debris is placed on the bottom of the trench and compacted before being buried with topsoil and other strippings from the road prism.

This method works well where usable subgrade material occurs fairly continuously below a veneer of unsuitable soil. The excavated trench material can

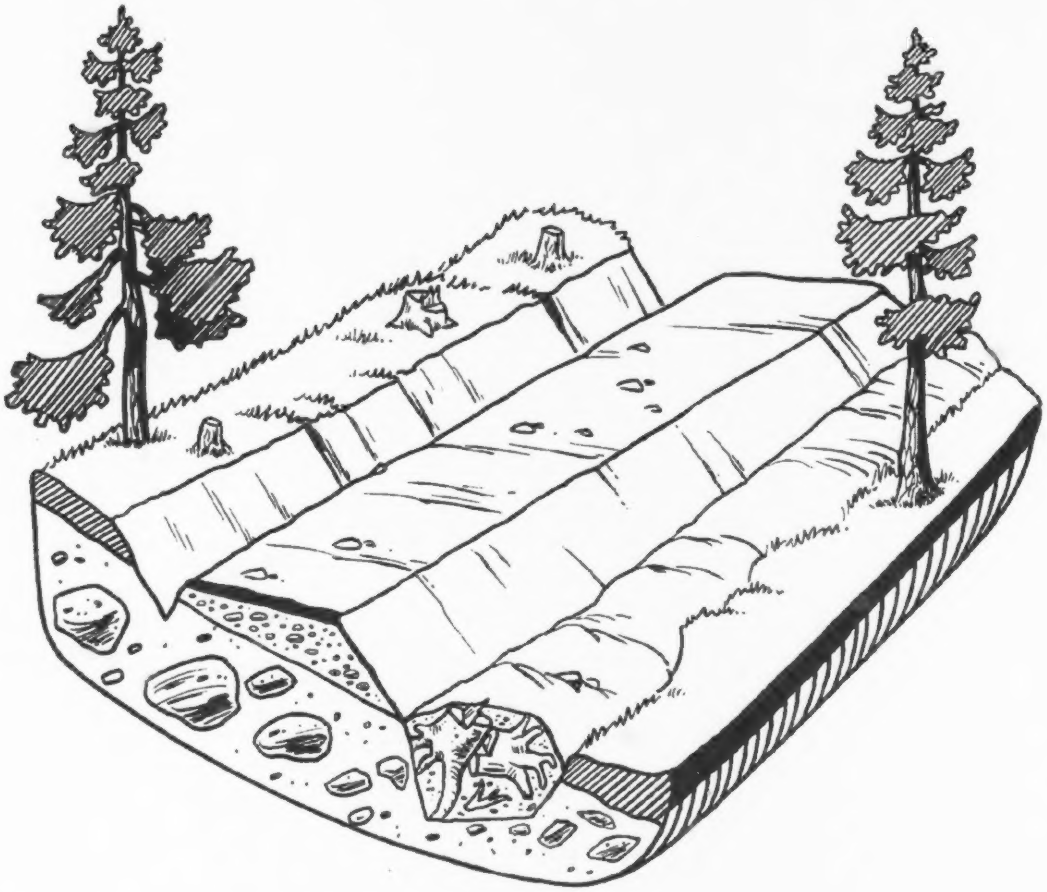


**Figure 13.** Slash and debris disposal by trenching.

be used to raise the subgrade above the normal groundline. Trenching should not be used on natural slopes with greater than 20% gradient, as it could undermine the road surface, causing long-term subgrade instability.

### Mounding or windrowing

With this technique, all slash and debris are accumulated along one side of the cleared width between the road prism and the standing timber. The woody debris is placed first and compacted by the grubbing equipment. Stripping material from the road prism is used to cover the slash with additional mineral soil, used as required to ensure that a minimum of 300 mm of soil cover is achieved. Because of the difficulty of maintaining an adequate soil cover on the downslope side, the results of this method on natural slopes with greater than 50% gradient are not easy to control.

### Pushouts

Pushouts should be located in natural openings along the cleared area and should be appropriate for the volume of material to be disposed of. Debris should not be pushed into standing timber, and the piles should be properly groomed to be stable and visually acceptable.

## *Scattering*

This process is similar to mounding and windrowing, but does not require the slash to be buried (Figure 14). In low-density stands, debris may be spread among the standing timber in natural openings along the cleared area, thus reducing the clearing width required for disposal. Care must be taken to avoid damaging the standing timber.

Scattering should be considered where:

- sidecasting slash and debris will not increase the likelihood of landslides
- fire and pest hazards are low and aesthetic concerns are not an issue.

Incidental burying may occur, but is not an objective. The material may be bunched or spread, but any continuous accumulations should be breached to accommodate drainage, snow removal, and wildlife passage.

Slash and debris can also be chipped, or ground up, and blown along the cleared area or into the standing timber, away from watercourses. In addition, chipping may limit erosion of exposed soils and facilitate revegetation.

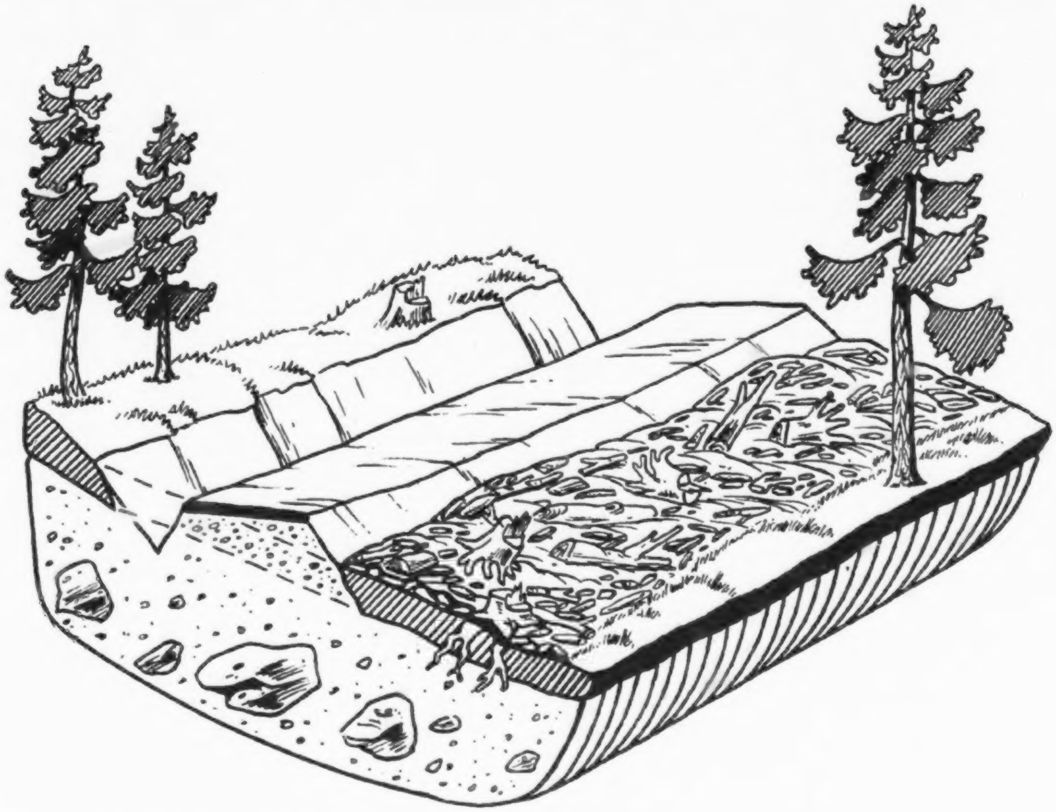


**Figure 14.** Slash and debris disposal by scattering.

### *Endhauling slash and debris*

Endhauling slash and debris from the road corridor is required in steep or unstable terrain where this material must be removed to maintain slope stability. It may also be required in areas with high recreational value where aesthetics may be an issue.

The approved waste area should be stable and well drained, isolated from streams or wet sites, and have a minimal adverse impact on other forest resources. Overloading of slopes should be avoided. Once endhauled, the slash and debris should be disposed of by burning, burying, or scattering.

Where possible and practical, stockpile organic and fine-textured soils for placement over abandoned borrow and waste areas to facilitate revegetation. All waste areas should be identified before construction.

Regardless of the disposal method used, ensure that the top of any remaining spoil material is below the road surface (to allow for snow ploughing and sight distance) and placed in a manner to allow surface water to drain away from the road.

## Subgrade construction

Storm and rapid snowmelt events should be anticipated during construction, and the associated surface runoff and intercepted subsurface flows should not be allowed to damage the subgrade or other resources. This means that ditches, cross-drain culverts, and any permanent or suitably sized temporary drainage structures should be constructed as water is encountered. Refer to Chapter 4, "Road Drainage Construction."

### *Construction surveys*

Construction surveys are conducted to re-establish the road centreline, and to determine the limits of the cut and fill slopes. They are also carried out to provide grade control during construction. Preferably, construction surveys are carried out after clearing and grubbing operations, but before primary excavation begins.

In some instances, construction surveys are mandatory. They are required for roads that will cross areas with a moderate or high likelihood of landslides as determined by a TSFA. An exception to this requirement occurs when a qualified registered professional will provide on-site inspections during construction and a statement of construction conformance after completion of construction indicating that the measures to maintain slope stability, stipulated in the design, were implemented.

All excavation equipment operators should be familiar with the use of construction survey stakes. Properly conducted, the construction survey ensures that excavation volumes are minimized and that the measures to maintain slope stability are correctly implemented.

Construction surveys normally include:

- marking of the clearing width boundaries
- establishment of new reference trees where the existing reference trees are located within the clearing area
- accurate establishment of the road centreline
- slope staking of cut and fill slopes based on actual site conditions (field calculation as opposed to following the design staking table)
- centreline location, design, and slope staking as needed to adjust for unforeseen site conditions.

When a forest road is being built in steep and broken terrain, the opportunity to construct a pilot trail ahead on the road right-of-way is often limited. Therefore, it may not be possible to completely separate the grubbing, stripping, and subgrade excavation phases. Under these conditions, slope staking should be done prior to any equipment activity. This requires flexibility to adjust the limits for excavation if material conditions are different from those assumed in the road design.

When a pilot trail is built, underlying material types can be examined and confirmed to match the road design. If the soil types differ, re-design of the geometric road design may be required to adjust the cut and fill slope angles as well as the movement of materials. Changes in soil types often result in a shortage or surplus of materials that can be remedied by a re-design.

Before primary excavation begins, ensure that the construction survey has been completed and any necessary re-designs have been incorporated into the slope staking. Slope stakes should include the horizontal and vertical offset to the designed centreline; cut or fill slopes, station chainage, and roadbed width.

Provide adequate protection of the slope stakes by offsetting and painting them with high-visibility florescent paint. Reference points should remain intact. Staking may be substituted by flagging or spray-paint as appropriate for the site conditions; for example, in areas where shallow organic soils overlie bedrock. For detailed procedures for construction surveys refer to *Manual for Roads and Transportation* (BCIT 1984).

### *Modifying the road layout and design*

If the road design does not reflect the field conditions actually encountered, then the road design may be modified to address those unforeseen conditions. Should a professional prescription not reflect actual field conditions, or if the layout and design revisions affect a prescription to maintain slope stability, then any design changes must be reviewed and approved by a qualified registered professional before construction begins.

Where the changes made to a previously approved layout or design could have a negative impact on forest resources, and these forest resources were protected under the original approved road layout and design, then the revised design must be approved by the district manager before construction recommences. Examples of changes include, but are not limited to, amending:

- the construction techniques, where the likelihood of landslides may be increased if they are not amended
- the location of the road outside the approved clearing area
- the construction technique within riparian management areas
- the number of crossings of a stream
- the design of a drainage structure affecting a fish-bearing stream

- the design of a major culvert or bridge
- the construction technique such that the road classification changes from a permanent to 5-year road
- the road width or design speed.

## Changes to road design to address unforeseen conditions

Where site conditions not anticipated by the design are encountered, work should be stopped at that location until:

- the extent of the problem is identified and recorded
- all resource impacts are re-assessed
- a plan for modifying the design to suit actual site conditions and to protect other resource values is developed
- the district manager's approval of the design modifications is obtained, if required.

*Situations where the hazard is low, and the risk of damage is low:*
Where the road **is not** in areas of moderate or high likelihood of landslides and the proponent determines the risk of adverse impacts on other forest resources to be low:

- note the road name, stations, and changes to the design on the drawings or road file and retain for future reference
- begin work with the amended design.

*Situations where the hazard is moderate or high, and the risk of damage is low:*
Where the road **is** in areas of moderate or high likelihood of landslides and the proponent determines the risk to other forest resources to be low:

- record in detail the problem and course of action taken, noting the discrepancy in the design and possible consequences to resources
- if changes to any professionally prepared prescriptions are required, obtain approval for them from a qualified registered professional, preferably from the original designer
- obtain the approval of the district manager for the changes to the design where the likelihood of landslides may not be reduced by the change
- mark the changes to the design on the drawings and retain them for future reference
- begin work following the approved, amended design.

*Situations where the hazard is moderate or high, and the risk of damage is high:*
Where the proponent determines the risks to other resource values to be high or very high, in addition to the above:

- in consultation with appropriate resource agencies or qualified registered professional, schedule an on-site review to determine a suitable course of action, and amend the design
- obtain written authorization from the district manager to continue work using the amended design
- monitor the construction continuously until the work through the high-risk area is complete to ensure the amended design is followed
- complete necessary professional statements, if required, for the professional designs.

### *Sidecast construction*

Sidecast—also known as cut-and-fill, or partial bench construction—is the most common forest road building technique. Excavated material from the uphill slope is pushed, or cast, onto the downhill slope to form a fill to support the outside portion of the running surface of the road (Figure 8).

Topsoil and slash, together with saturated and other unsuitable soils, should not be used as road fill. These materials should be removed because they have a very low strength and readily fail under vehicle loading. However, stumps, roots, and embedded logs may be placed outside of the subgrade width in areas of low likelihood of landslides (Figure 9).

Crawler tractors and excavators are often used for sidecast construction. Soil is pushed or cast down the slope from the top of the road cut until the desired subgrade width is achieved. If this fill material is not properly compacted, settlement will likely occur, leading to slumping at the shoulders, and settlement or tension cracks in the road surface.

The fill material should be "keyed-in" or "notched" into the slope, after all organic material and unsuitable soils have first been removed from the road prism. The notch should be sufficiently wide to allow equipment to work. The fill should be built up in shallow lifts and compacted using the road-building machinery, or, ideally, roller compactors. Properly compacted fills have a higher load-carrying capacity, and tend to shed water rather than absorb it. This results in a more stable, erosion-resistant subgrade, which requires less maintenance while minimizing the potential for adverse environmental impacts.

## Full bench construction

Full bench construction is a measure often used to maintain slope stability. The excavated material will be hauled away (see "Endhauling," below) to an approved waste area, not wasted along the slope below the road unless specified by a qualified registered professional.

Excavating the outside edge of the road prism last can minimize spillage. By pulling the remaining material into the road prism, only inconsequential volumes of material will spill down the slope.

## Endhauling

Endhauling is a road construction practice often used to maintain slope stability, when done in conjunction with full bench construction. It can also apply in gentle terrain where road cuts, such as through-cuts, produce a surplus volume of material. Endhaul is the transportation of surplus excavated material from the construction site to an embankment area or waste area (also known as a spoil site) situated on stable terrain. Endhauling is an integral part of the road-building operation, rather than a distinct phase of construction, as site conditions dictate how and to what extent this practice must be adopted.

### Location of waste areas

While surplus excavated material should be used in road fills, excessive volumes should be hauled to waste areas. Potential waste areas should be identified during the field reconnaissance and incorporated into the road design. Waste areas should be located outside riparian management areas. They should take advantage of swales, depressions, benches, and shallow slopes; ideally, they should use old borrow pits or quarries. It is important that they maintain natural drainage patterns. Waste areas should not be located in areas of moderate or high likelihood of landslides, or at the crest of a slope or top of an escarpment.

If waste areas are located where there is moderate or high likelihood of landslides, they must be identified in the measures to maintain slope stability. The qualified registered professional should prescribe treatment of the waste area (such as fill slope angles and height of fill) to ensure slope stability is not compromised.

Care must be taken when placing waste material in the selected sites to ensure stability of the waste pile and to minimize erosion. Consider:

- placing the coarse material on the bottom and the finer-grained material on top
- using topsoil to cover the pile to aid revegetation and limit surface erosion

- not exceeding the natural angle of repose of the material
- "benching" the sides of the pile when heights exceed 5 m
- crowning, sloping, and grooming the pile to ensure that the surface does not pond water
- installing sediment control devices below the waste area to capture and prevent sediment transport beyond the waste area until the pile is revegetated.

## *Loose (trucked) material volume*

As discussed in the section "Correction factors to adjust for swell and shrinkage of materials," in Chapter 1, "Road Layout and Design," soil and rock material increases in volume when excavated from the bank (refer to Figure 3). Therefore, to estimate the loose volume (sometimes referred to as **trucked volume**), the bank volume, as measured from road cross-sections, must be increased by applying a suitable **swell factor**, according to the soil or rock type.

*Examples of swell factors* to convert from bank volumes to loose volumes are:

1.05 to 1.15 for sand and gravel,

1.15 to 1.35 for mixed soils, and

1.50 to 1.65 for blasted rock.

Refer to equipment supplier handbooks on materials handling and earthmoving to obtain representative swell factors for specific material types encountered during road construction.

### Example

Loose volume = Bank volume × Swell factor.

Example: If the bank volume of a proposed rock cut is 9 $m^3$ measured from drawings, what will the loose volume be, or in other words what volume will have to be trucked? Assume a swell factor of 1.50.

Solution: Loose volume = $9\ m^3 \times 1.50 = 13.5\ m^3$

## *Drilling and blasting*

### Blasting operations

The drilling and blasting techniques used should:

- minimize disturbance to forest resources and existing improvements
- minimize the potential for landslides or slope instability.

Many disturbances come directly from flyrock, such as:

- rocks embedded in trees, presenting hazards to fallers and mill workers
- trees blown over or otherwise damaged by air blast and flyrock
- carpeting of the forest floor with rock fragments, making reforestation difficult
- pile-up of blasted rock against trees
- physical damage to powerlines or other structures
- detrimental impacts to watercourses, creeks, or streams
- rocks hung up on slopes, presenting hazards downslope.

Blasting can create excessive site disturbance or increase hazards for slope instability in a number of ways:

- blast vibrations during periods of unusually wet soil conditions may lead to potential slope failures
- rock fragments may be projected outside the road prism and beyond the clearing width
- material may pile up or run out beyond the clearing width, especially on unstable slopes
- overbreak of uphill slope may create instability
- overbreak may induce rock fall or potential for rock fall later.

The objective of blast design is to fracture the rock mass in a controlled manner and permit the rock to move in successive stages toward a free face. Over-confinement of the rock at any point within a blast may lead to poor fragmentation and cause flyrock. Blasters should be able to assess rock and site conditions, formulate appropriate blast designs, learn from previous results, and immediately revise field practices to reflect changing conditions.

Where site conditions are complex or beyond the experience of the blaster, or the risk is severe, guidance from a specialist explosives engineering consultant should be sought. Good blast design considers the following:

- rock type and structure, including rock hardness, stratification, joint and dip orientation, and block size
- borehole diameter, length, and orientation—vertical drilling versus horizontal drilling—as appropriate to the blast objectives
- groundwater conditions
- burden and spacing
- weight and type of explosives
- collar length and stemming

- detonation method
- delay pattern
- measures for flyrock control.

Flyrock, or excessive throw, can originate at different points in a blast. It can come from:

- the forward movement or throw of the entire round
- the borehole charge breaking through the burden
- gas pressure forcing fragments into the air from within or around the collar of the borehole.

The degree or threshold of rock movement that constitutes flyrock varies depending on the blasting application. The Forest Road Regulation defines flyrock as "airborne rock displaced beyond the road prism by blasting." Thus, the goal of blasting operations on forest roads is to minimize the amount of rock that is cast beyond the road prism.

It may be difficult to eliminate all flyrock from every blast because rock conditions and excavation requirements vary and can change frequently along the road location. Nevertheless, blasting crews and supervisors should be able to demonstrate that the practices they adopted were appropriate for the observed conditions, and that their practices were altered in subsequent blasts in response to changing rock conditions.

## Causes of flyrock

Flyrock can be caused by:

- excessive amount of explosive
- inadequate burden
- faults and cracks in the rock
- inadvertent loading of explosives into voids or fissures in the rock
- spacing and burden that exceeds the depth of borehole
- inadequate type or amount of stemming
- over-confined shots
- inappropriate drilling and loading patterns
- poor selection of delay sequences.

Measures to minimize flyrock include:

- precisely orienting and drilling boreholes to maintain desired burden and spacing

- determining the appropriate quantity of explosive charge and distribution of this charge within and between boreholes
- specifying a firing pattern and selecting the delay sequence.

Where the rock hardness, weathering, and jointing is suitable, use of alternative rock excavation methods should be considered, such as rock breaking with a backhoe-mounted hydraulic hammer, and ripping by an excavator.

After a blast design has been prepared, additional measures may be taken to reduce the residual risk of flyrock. These include covering the blast area or flyrock-prone portions of the blast area with backfill materials, or by using blast mats.

A rule of thumb is to backfill to a depth not less than the collar distance (minimum of 1 m) with granular overburden. Backfilling must be done with extreme care to prevent damage to any exposed components of the blast initiation system. If backfilling is not practical on sidehill rock cuts, blast mats or guard logs may be suitable alternatives.

Rubber blast mats, constructed from tires, and steel mats, constructed from wire rope or chain-link type materials, are available. To avoid inadvertent damage to the initiation system, blast mats must be placed with care and not dragged into position over the loaded blast area.

Guard logs, secured by cables if necessary, may be placed prior to, or after, drilling and loading operations. In remote locations they are a convenient, if somewhat less effective, alternative to backfilling or blast mats.

## Secondary blasting

Small-diameter drilling equipment, such as hand-operated rock drills, may be useful for some special construction tasks. Alternative construction methods can eliminate the need for drilling and blasting altogether. Non-explosive rock fragmentation agents can also be used.

For blasting individual boulders, a device that uses the energy from a shotgun-type cartridge may be considered. A borehole is drilled in the boulder and filled with water. When the unit is fired, a pressure impulse is generated in the water column, cracking the rock. Another option is a directional-blasting cone. Hydraulic excavator-mounted rock breakers are useful tools for many construction situations and rock types.

## Controlled blasting

Controlled perimeter blasting refers to a number of techniques that provide a competent, stable excavation in rock. These techniques, including pre-shearing, post-shearing, and cushion blasting, minimize overbreak—which is the fracturing and loosening of rock beyond the intended final boundary of the excavation.

The most common controlled blasting technique is pre-splitting, also known as pre-shearing. With this technique, a series of closely spaced holes, 600 to 900 mm apart, are drilled along the boundary of the excavation. These holes, usually 51 or 76 mm in diameter, are loaded relatively lightly and fired simultaneously just prior to initiation of the adjacent production holes. The objective is to crack the rock along the blast perimeter, reflect the energy of the production blast, and direct the fragmented rock mass away from the back wall. The holes are usually applied in downholing situations and require precise alignment. A number of explosives have been designed specifically for controlled perimeter blasting.

## *Overlanding*

Overlanding is a construction technique in which road fill is placed on undisturbed organic soil, stumps, and vegetative material (Figure 15). The objective is to distribute vehicle loads over weak soils using the inherent strength of the vegetation mat to support the weight of the road fill without disturbing subsurface groundwater flows. It is important that the vegetative mat remain undisturbed to prevent the unsuitable saturated soils below the mat from mixing with the imported subgrade material.

When stump heights will interfere with the finished road surface, stumps can be inverted so that the root mat of the stump partially supports the fill material (Figure 16). Generally, overlanding is done on relatively low, wet flatlands or over shallow depressions on stable terrain with slopes less than 20%.

Ditching is not recommended, unless the ditch is located a sufficient distance away from the road to prevent weakening of the natural vegetation mat under the road. Furthermore, ditches should not be excavated to obtain the required road fill materials. The undisturbed mat should allow subsurface water to flow under the road prism. Any required fill material should be imported from a suitable borrow area.

Overlanding techniques can include placing a layer of unmerchantable trees, logs, stumps, roots, or branches—known as corduroy or puncheon—perpendicular to the road centreline to form a mat for the road fill. The mat separates the road fill from the underlying soil and supports the fill. It is important to separate the underlying soil from the road fill because infiltration of topsoil into the granular material will degrade the strength of the road fill. The corduroy should be completely buried to prevent decomposition.

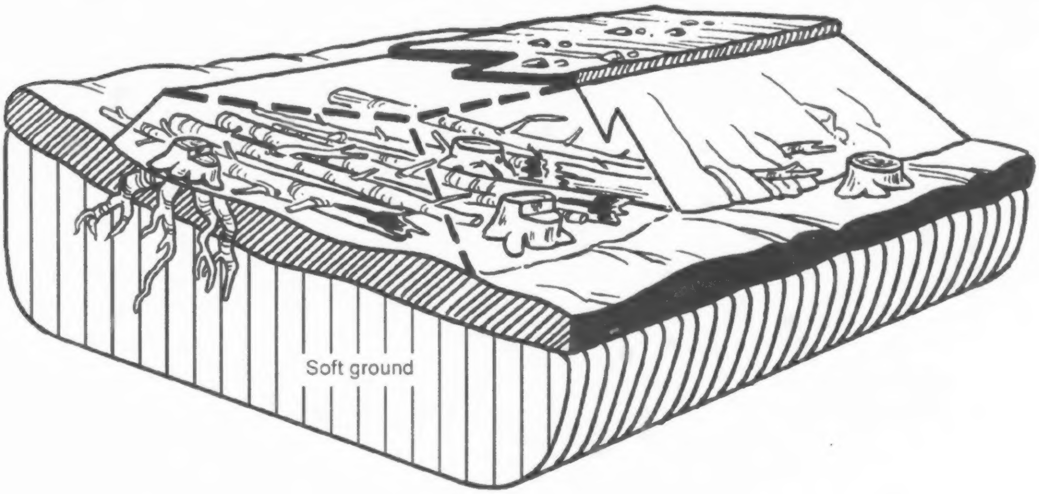


**Figure 15.** Overlanding cross-section with corduroy.

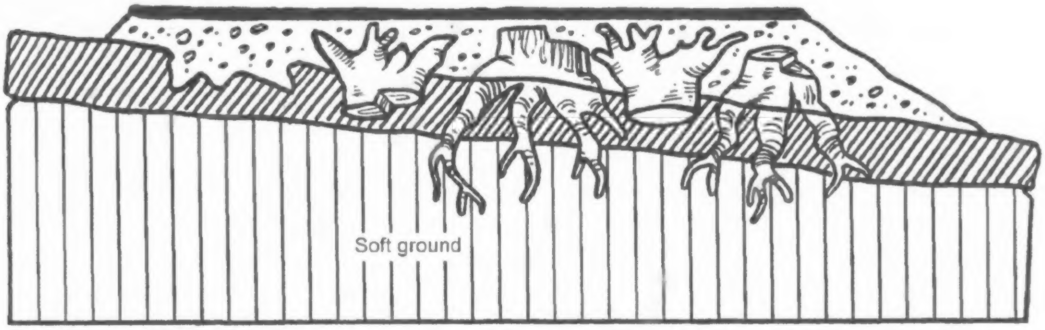


**Figure 16.** Overlanding cross-section with inverted stumps.

Geosynthetics can also be used to separate the underlying soil from the road fill. This is a method for separating materials and reinforcing the subgrade, but it requires careful preparation of the pioneer trail. A relatively smooth surface is preferred to prevent underlying debris and rock puncturing the geosynthetic. Where the risk of puncture is high, heavier geosynthetics are required to cover coarse ballast rock, or stumps.

Geosynthetics can also be used to reinforce the road fill structure. The subgrade and road fill must be built and compacted carefully to develop the necessary friction (or cohesion) between the fabric and adjacent material. The geosynthetic should be "anchored" within the structure to enable tensile forces to develop in the fabric under loading. This is difficult to achieve in the weak soil conditions typically found when overlanding. Therefore, in this application, the primary function of the geosynthetic is to separate the materials. Further information about the functions of geosynthetics and their application to forest roads can be found in *Basic Geosynthetics: A Guide to Best Practices* (Fannin 2000).

The amount of fill that is placed and compacted during overlanding must be sufficient for the anticipated loads. The depth of material is a function of soil properties (particularly bearing capacity), vehicle loading, season of use, and life expectancy of the road. The use of geosynthetics or puncheon can reduce the amount of road fill required and may also reduce future road maintenance requirements.

### Borrow pit locations

Borrow pits and quarries must be excavated outside of riparian management areas. Ideally, they should be located where there is sufficient distance between the pit and the riparian management area to allow construction of sediment control devices that will minimize sediment transport beyond the pit.

The base of the pit should be sloped away from the stream, and drainage structures should be built to prevent water from entering the stream directly from the pit. Natural surface drainage patterns should be maintained.

Where the pit or quarry may encroach on the riparian management area, specific approval from the district manager, in writing, is required before works begin. Note that the district manager must first consult with the designated environment official regarding the approval of the pit.

If known acid-generating rock is encountered in pit development within a community watershed, further expansion of that pit should cease and backfilling to cover the acid-generating rock should begin. Drainage from the pit should be directed away from any stream. Acid-generating rock should not be used for construction purposes.

### Winter construction of permanent roads

Where no other option exists, permanent roads may have to be constructed in the winter. Snow, ice, and frozen material should not be placed in the road fill. These materials cannot be easily compacted and settle when they thaw. This thawing then saturates the fill and creates voids that readily collapse. The resulting fill is not only unstable and low in strength, but also highly erodible and often a source of sediment, potentially causing severe damage to streams during the spring break-up period. Refer to "Construction and use of snow and one-season winter roads," below, for use of snow, ice, and frozen material.

### *Protecting erodible fills located within floodplains*

Where embankments must be constructed within active floodplains, action must be taken to prevent erosion of those embankments. The best way is to form the entire embankment of non-erodible material. Where this is not possible or practical, armouring of the fill is required.

Table 7 indicates the stream velocities that can erode different-sized materials.

If the embankment is to be formed by one of the materials in Table 7 and will likely be subject to velocities at least equal to those corresponding to that material, then armouring is required. There are several choices of armouring material:

- angular and durable rip rap
- sand bags (a short-term solution only, as bags break down over time)
- concrete: concrete blocks (quick, easy installation), sprayed concrete (shotcrete or gunnite), or poured-in-place concrete (uncured concrete products should be kept isolated from the stream until the concrete has cured)
- binwalls (for velocities less than 1 m/sec or in conjunction with rip rap and where suitable fill material—cobble, coarse gravel—is readily available)
- other commercial erosion control systems.

Whatever material is used, it should be:

- placed below the point of scour
- keyed in so that fill stability is maintained
- installed so as to prevent undermining of the fill
- sized to resist peak flow velocities
- graded to act as a filter to resist movement of underlying soil through the armouring material.

**Table 7.** Example erosion velocities.

| Material | Diameter (mm) | Mean Velocity (m/sec) |
|---|---|---|
| Silt | 0.005 | 0.15 |
| Sand | 1 | 0.55 |
| Fine gravel | 10 | 1.0 |
| Medium gravel | 25 | 1.4 |
| Coarse gravel | 75 | 2.4 |
| Cobble | 150 | 3.3 |

### Litter, petroleum products, and other waste materials

All workers on the site should be familiar with the requirements for the use, storage, and disposal of litter and of equipment fuel and servicing products. Those most commonly associated with road construction are:

- petroleum products: waste oil, oil and grease containers, and spoiled fuel
- refuse: camp garbage, waste paper, old machine parts, and damaged culvert pipe
- batteries and battery acid
- sewage and litter: where camps are to be established, sewage disposal via permitted septic systems is required
- fuel storage: permit from the Department of Fisheries and Oceans is required for the establishment of fuel tank farms

Petroleum product spills are common and actions to contain the spill must be taken. Proponents should have a spill response kit on hand and ensure that all personnel are familiar with spill containment procedures.

Spill kit contents will vary by type of work, potential size of spill, and impact potential. Spill response equipment may be required for incidents from minor hydraulic leaks to major watercourse spills. At a minimum, each machine should have a spill kit with extra absorbents in the support vehicle.

As appropriate and in accordance with the *Waste Management Act*, waste and contaminated materials may be disposed of either by being:

- burned or buried, or
- contained and removed from the site to an approved disposal location.

## Stabilizing the subgrade and surfacing the road

### Ballasting

Ballasting is the use of rock to construct the road subgrade where other available material is incapable of supporting the design traffic load during the period of use.

Generally, suitable ballast material should:

- drain well
- form a structurally competent fill
- compact well
- resist erosion.

## *Surfacing*

Surfacing the subgrade with pit-run gravel or crushed rock aggregate may be required for the following reasons:

- to form a driveable or gradeable surface
- where subgrade material is highly erodible and needs to be protected from water or wind action
- where subgrade material will not support traffic loading during periods of use.

### Surfacing material selection

Surfacing materials include well-graded crushed rock and well-graded pit-run gravel aggregates. These materials should consist of inert, clean, tough, durable particles that will not deteriorate when worked (handled, spread, or compacted), or when exposed to water and freeze-thaw cycles. Aggregate particles should be uniform in quality and free from an excess of flat or elongated pieces.

The aggregate should be well-graded; that is, it should contain an even mix of all particle sizes. This is desirable for compaction as well as to ensure a durable wearing surface. Refer to the Ministry of Transportation *Standard Specifications for Highway Construction* for more detail and specifications for well-graded aggregates.

When the source material is a poorly graded material, screening the material to remove the excessive particle sizes or blending in the deficient material size should be considered.

Crushed aggregate is expensive to produce and should be protected with a base coarse stabilizer (e.g., calcium chloride or magnesium chloride, installed to the manufacturers' specifications) to prevent the loss of fines. Specifications for high fines crushed gravel should be obtained and rigidly applied when use of a calcium chloride or related stabilizer is being considered. Note that many stabilizers may not be acceptable in community watersheds or near licensed water intakes.

## *Surfacing compaction*

Compaction of the subgrade and surface through the use of equipment designed for this purpose will increase the load-carrying capacity of the road bed and reduce the volume of surfacing material that will be required to maintain the road bed during its service life.

For optimum strength, the preferred material should be placed in uniform lifts compatible with the compaction equipment that is to be used. Each lift should be uniformly compacted before being covered with the next lift. To achieve the maximum compaction level, the material should be compacted at the optimum moisture content. A well-compacted material will generally resist human footprint depressions.

To achieve maximum compaction, moisture content is critical. Material that is too dry or too wet will have a lower compaction level. During the spreading phase, water should be added to dry material and the saturated material allowed to dry to achieve the optimum moisture content.

## Construction and use of snow and one-season winter roads

Throughout much of the interior of British Columbia and in a few areas along the coast, winter climate conditions of frozen ground or deep snow fall, together with fine-textured soils and muskeg (bog) ground conditions, mean that forest operations are best conducted during the winter months. By using snow or frozen ground as the running surface, snow and one-season winter roads have a lower environmental impact than all-weather roads. The roads are constructed during the early part of the winter, so that harvesting can be completed before snowmelt and the break-up of frozen ground in the spring. If there is insufficient snowpack, these road types cannot be constructed.

Snow roads and one-season winter roads use the strength of ice and snow to produce a stable road bed that will support the design vehicle axle loads. In areas with heavy snowfall, the main reliance will be on the snowpack. Where snow is scarce, a small excavation may be required for the construction of a one-season road. In either case, weather is the essential and unpredictable factor in the construction process, and logistics are key to constructing and using winter roads effectively. Where mid-winter thaws are common, short spur roads can be constructed, used, and deactivated in a matter of weeks.

Generally, watercourses are frozen for the life of the road, and in many cases drainage structures may not be required. Snow fills are compacted across small streams and gullies with the use of log bundles to pass any seepage that may occur or to reduce the volume of snow required. Where mid-winter thaws are common, culverts may be installed in the snow fill to accommodate possible flowing water.

Deactivation of these road types should be co-ordinated with operations and be completed prior to the spring freshet. All natural drainage channels should be restored while road access is available. Logs should not be left in stream channels and snowfills should be breached to prevent the damming of watercourses. Though mid-winter thaws can disable even a well-built road, the high-risk period begins during the spring break-up period. In many areas during this period, snowmelt occurs very quickly, resulting in rapid overland flows of meltwater, high flows in watercourses, and an extreme softness of soil materials, which renders them highly susceptible to erosion. Any soils that have been mixed with snow become fluid and highly susceptible to mass erosion. Spoil material piled on top of a snow layer can become unstable on even gentle side slopes. For more information on deactivation techniques, refer to Chapter 6, "Road Deactivation."

## *Snow road construction*

Snow roads are a form of overlanding construction in which clean snow and ice are used as fill (Figure 17). Suitability of materials is not critical because materials are frozen and can support the design vehicle axle loads. Snow roads are appropriate for providing access across gentle terrain to winter-harvest–only areas, which are located mostly in the Interior. Snow roads are limited to terrain with slopes less than 20%, unless there is a very deep snowpack. The surface is often built up with ice by using water in areas of flat terrain with a minimal snowpack.

No excavation is permitted (cut slopes or ditches) other than the removal of the occasional stump that cannot be readily covered with snow and ice. The road may be reconstructed and re-used each winter in the same location.

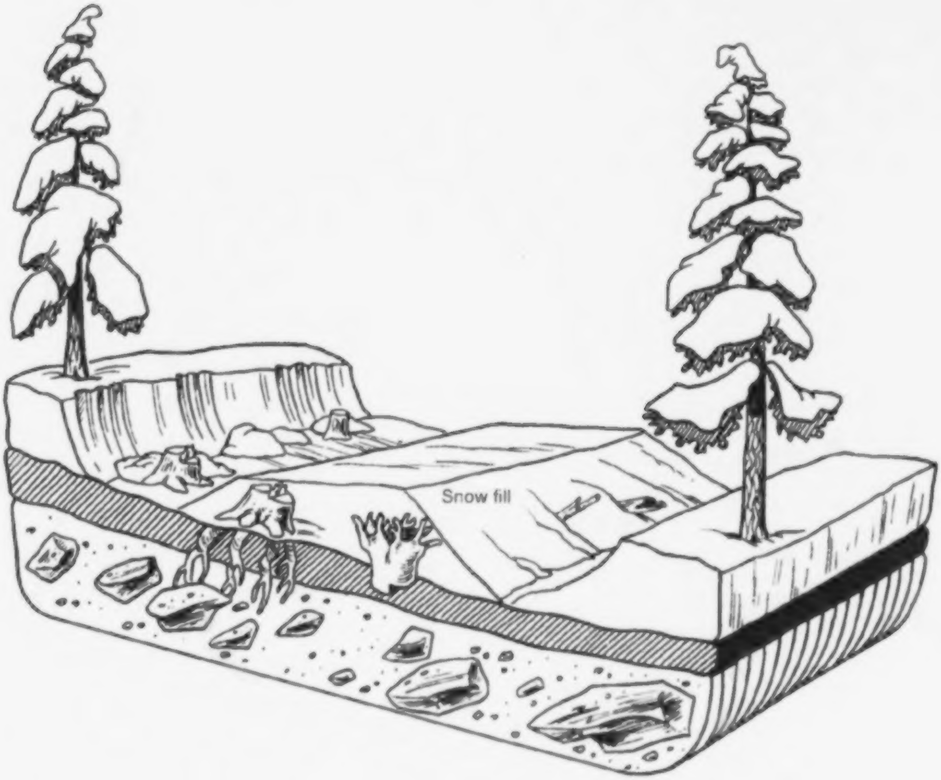


**Figure 17.** Typical snow road.

## *One-season winter road construction*

Similar to snow roads, one-season winter roads are constructed mainly from snow and ice, with a minimal amount of soil (10–20%) to assist the freezing-in of the road, or to provide a more durable surface where infrequent mid-winter thaws may occur. They are suitable for temporary access to winter harvest areas for one season only and are not intended to be reconstructed.

Because of the high risk of sediment deposition during the spring freshet, soil should not be mixed with snow in the riparian management area of stream crossings. Log bundles and clean snow only should be used in gullies and riparian areas.

Stripping is to be limited to the removal of large stumps that cannot be easily covered with snow or ice. Cuts into mineral or organic soil should not exceed 300 mm in depth for sustained distances on slopes greater than 15% or 500 mm in depth for short distances on steeper slopes up to 35%. Figure 18 shows a finished one-season winter road.

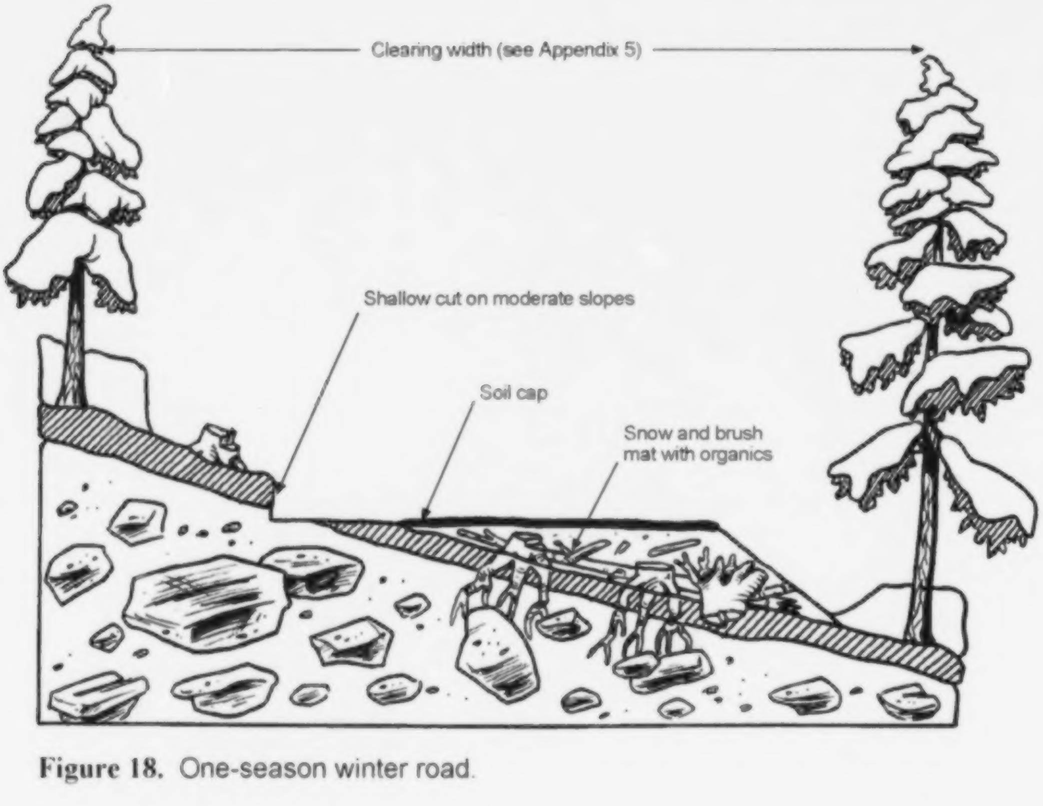

Clearing width (see Appendix 5)
Shallow cut on moderate slopes
Soil cap
Snow and brush mat with organics

**Figure 18.** One-season winter road.

For one-season winter roads, a mixture of dirt and snow on the road surface can provide a stable roadway when frozen, but it becomes highly liquid during spring thaws. Any appreciable side slopes or gradients may result in mass erosion from the roadway. Waste areas constructed on top of snow can become unstable during melt periods, or can create a situation where meltwater on the roadway cannot run off the road but only run down it. To address these concerns, consider the following:

- plan for and install deactivation works during the original road construction wherever possible—this will help to decrease the amount of maintenance and deactivation needed during the summer months, when these types of roads are generally impassable
- construct swales, insloping and outsloping the subgrade, or install log-filled cross-ditches so deactivation requirements will be reduced
- where possible, overland the road with a brush mat and snow excavated from the clearing width
- use a small amount of unfrozen dirt as a freezing agent to construct the road surface
- breach berms and snowbanks at intervals of no more than 50 m
- smooth the road surface at the time of construction to avoid building in ruts and other irregularities
- construct waterbars on long grades
- remove fills in natural drainage channels
- pull back soil-contaminated snow fills in the vicinity of stream crossings
- take measures to prevent sediment from entering streams around crossings.

### *Road use*

Mid-winter thaws are commonplace in the Interior and can disable even a well-built road. Because of heavy use and adverse weather, rutting and deformation of the road surface can occur as the subgrade begins to thaw. Roads should be used only in frozen conditions.

- Schedule night hauling when temperatures are expected to be above freezing during the day.
- Strictly control all light traffic during unfrozen conditions.

## Construction of 5-year roads

The introduction of stumps, roots, and embedded logs into the road fill under the travelled portion of the road reduces the long-term stability of the fill. The buried organic material will deteriorate over time and begin to settle. This removes support for the applied wheel loading and results in rutting of the road surface. Water ponding in the ruts may saturate the road fill and lead to failures. Thus, the use of roots, stumps, and embedded logs in the road fill should be restricted and the requirement to permanently deactivate these roads within 5 years of construction enforced.

The life of a 5-year road may be extended up to 10 years, but only if regular inspections indicate that the road fill is stable and can still support the design vehicle axle loads. If the road fill begins to show signs of failure, or after the 10 years have passed, the road must be permanently deactivated or reconstructed.

## Surface erosion and sediment control

Control of surface erosion and subsequent sediment transport during road construction is a concern where there is direct or indirect connectivity to aquatic habitat or aquatic resources. Soil disturbance is inevitable from most road construction or modification activities. As erosion control has a generally higher level of effectiveness than sediment control, the primary goals should be, firstly, to minimize potentially damaging erosion of the disturbed sites, and, secondly, to limit the transport of sediment from these sites.

### *Surface soil erosion control techniques*

The best way to minimize soil erosion is to cover all exposed soils with vegetation. This vegetative cover should be established as soon as possible to protect and hold soil particles from the erosive effects of rainfall. It should be applied as soon as slopes are completed, rather than after the entire road project is complete. Prompt revegetation not only helps for erosion control; it also helps to prevent the spread of noxious weeds.

Surface soil erosion control techniques include, but are not limited to, the following:

- confinement of sensitive operations to periods of dry weather and selection of equipment that will create the least disturbance
- compliance with local rainfall shutdown guidelines
- temporary diversion and/or impoundment of stream flow to reduce the exposure of disturbed soil to flowing water during stream-crossing structure construction
- installation of silt fencing or erosion control revegetation mats
- installation of rock check dams or placement of rip rap to reduce water velocity and scour potential
- installation of sediment catchment basins.

Refer to the Ministry of Forests *Best Management Practices Handbook: Hillslope Restoration in British Columbia*, and other references cited, for more detailed information on control of soil erosion and sediment transport.

## Sediment control techniques

Consider the following measures to minimize sediment transport away from the road prism:

- apply grass seed as soon as practical following completion of an area of construction
- install silt fencing, hay bales, or erosion control revegetation mats
- install rock check dams or place rip rap to reduce water velocity and scour potential and to provide for temporary sediment retention
- install sediment catchment basins
- confine sensitive operations to periods of dry weather, minimize traffic through these areas, and select equipment that will create the least disturbance (e.g. rubber-tired or rubber-tracked machinery)
- for stream culvert installations, use temporary diversion or impoundment of stream flow to reduce the exposure of disturbed soil to flowing water (but obtain prior agency approval if required).

Refer to the Ministry of Forests *Best Management Practices Handbook: Hillslope Restoration in British Columbia* for more detailed information on control of soil erosion and sediment transport.

## Revegetation

Grass seeding with a grass and legume seed mixture on exposed soil is the most common and usually the most cost-effective means of treating roads to prevent erosion.

There is a variety of erosion seed mixes available that provide for rapid germination and long-term growth to provide a solid sod layer. Care should be taken to ensure that the seed species selected are compatible with domestic livestock. For some areas, it may be desirable to select a seed mix that will not encourage grazing by livestock.

- Apply seed in accordance with vegetation specifications to all exposed soil that will support vegetation. For example, seed areas of road cuts, ditchlines, fill slopes, inactive borrow pits, waste areas, and other disturbed areas within the clearing width.
- Dry-broadcast seeding immediately following construction works is the most common means of applying seed, whether by hand using a handheld "cyclone" type seeder or by machine such as a vehicle-mounted spreader or a helicopter-slung bucket. In most cases, a light application of fertilizer will assist in initial establishment and growth.
- Hydroseeding (i.e., a mixture of seed, fertilizer, mulch, tackifier, and water applied as a slurry mix) can be used for revegetation of roads.

although it is more costly. It is the most effective method of obtaining growth on steep or difficult sites.

In some locations, natural revegetation may be appropriate. Note that this option requires the district manager's approval, but the proponent is still responsible to ensure that the area is completely revegetated within 2 years.

## Road works shutdown indicators and procedures

This section describes the visible weather and soil-related conditions that proponents can use on site to help them determine when forest road operations should be shut down because works are causing, or may imminently cause environmental damage.

The objective is to reduce potential adverse impacts on forest resources such as:

- slope failure originating within the limits of the construction site or in the adjacent terrain
- surface erosion of exposed soils
- sediment transport to fish streams.

When a qualified registered professional develops a prescription for a road-related activity in areas of moderate or high likelihood of landslides, that prescription should contain site-specific, weather-related shutdown indicators, and start-up requirements.

### *Activities in saturated soils*

Listed below are activities that may normally be conducted in areas of saturated soils:

*Roadway construction:*

- hand falling
- blasting in low landslide hazard terrain units
- installation of clear span stream culverts where sedimentation will not reach fish streams, fish lakes, marine-sensitive zones, or community water supply intakes
- installation of cross-drain culverts where sedimentation will not reach fish streams, fish lakes, marine-sensitive zones, or community water supply intakes
- placement of shot rock surfacing
- bridge construction (excluding instream works).

Under certain conditions, some works can be performed without adversely affecting resources. For example, machine falling or gravel surfacing may be done on competent well-drained soils.

*Roadway maintenance:*

Only in emergencies is it appropriate to carry out maintenance during high water flow or saturated soil conditions. For example, if a culvert is plugged and is starting to, or will imminently, wash out a roadway, fill, or structure, then the problem should be rectified immediately. Failure to carry out such works may result in loss of improvements and unacceptable impacts to other resources. If adverse impacts indeed occur during such maintenance work, the appropriate agencies should be notified at the earliest possible time.

### *Procedures for shutting down operations*

Works should cease before soils are visibly soft or muddy and associated silty waters or sediment are flowing toward streams, lakes, or marine-sensitive zones or where such conditions are reasonably anticipated to develop. The equipment operator is usually in the position to first recognize signs of pending erosion on site.

Before shutdown, drainage should be controlled to ensure that no subsequent adverse impacts occur. Protective measures should be carried out in the localized work area, primarily on sites where works are not at a completed and controlled stage. Note the following general requirements:

- Minimize sediment delivery from stockpiled erodible soils.
- Leave drainage systems functional.
- Add water control measures such as cross-ditches and waterbars, where appropriate.

### *Limit use of the road to minimize adverse impacts*

Traffic should be restricted where works are shut down because of saturated soil conditions. Temporary signs should be posted warning of the danger, and the district manager should be advised of the necessity to close the road to all traffic.

## Suggestions for further reading

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# 4. Road Drainage Construction

## Introduction

To minimize negative impacts on the environment, forest road drainage systems should maintain surface drainage patterns. This is accomplished by installing drainage structures and ditches that are sound, functional, and stable.

This chapter discusses:

- maintaining surface drainage patterns, both during and after construction
- temporary stream crossings
- ditch construction considerations
- cross-drain culvert location and installation
- backfilling and compaction around pipe culverts
- log culvert design and construction
- ford design and construction on non-fish streams.

## Maintaining surface drainage patterns

To maintain surface drainage patterns, water should be kept in its own drainage area, unless moving it to another area is necessary to avoid unstable or sensitive soils.

The potential for adverse upslope, downslope, and downstream impacts should be considered before culvert locations and outlet controls are determined. Measures to accomplish the latter include installing flumes or rip rap, or carrying drainage flow farther along the ditchline to discharge it onto stable slopes.

Drainage systems are used to intercept and manage surface or subsurface drainage. If the soils are easily erodible, the ditch gradient, alignment, or cross-section may need to be changed, or extra culverts added, to reduce the distance over which water will have to be carried.

To minimize sediment delivery to streams, the water conveyed in ditches and cross-drain culverts should not discharge directly into streams. These flows should be allowed to settle out through the natural vegetation on the forest floor before reaching any stream. Alternatively, these flows can be filtered in other ways, including the use of settling basins or geosynthetics, until vegetation can be re-established.

Drainage systems, whether permanent or temporary, should be constructed concurrently with subgrade construction. For a tote road or pilot trail, these should be functional to accommodate surface and subsurface drainage runoff throughout the construction period. Permanent structures should be installed during the construction period, and temporary structures removed.

Temporary structures, such as cross-ditches, swales, and open-topped culverts, should be constructed as water is encountered. Such structures should be capable of accommodating the peak flows likely to be encountered during construction. If the site is left unattended and a storm takes place, the in-place drainage structures should handle the runoff without damage resulting to the road or other resources.

*Practices to control drainage during construction:*

- Stockpile an adequate supply of culverts, rip rap, geotextiles, silt fencing, and grass seed on-site for immediate and future use, and to avoid construction delays.
- As water is encountered, establish adequate drainage to ensure flows are controlled and, where required, water quality is maintained should a peak flow event occur.
- Construct the final drainage structures as early in the construction process as practicable.
- Construct silt traps, armoured ditch blocks, and aprons as construction progresses or as soon as soil conditions allow.

*Practices to protect water quality:*

- Avoid working in areas of ponded water or saturated soils where this could result in negative impacts on other forest resource values.
- Construct stable cut and fill slopes.
- Avoid in-stream work as much as possible. Where in-stream work is necessary, obtain appropriate agency approval before starting the work.
- Install sufficient cross-drains and ditch blocks to keep ditchwater from eroding the ditchline.
- Install erosion-resistant aprons at the inlet and outlet of culverts.
- In ditches, use armouring, geotextile or silt fencing, blocks, or traps to minimize erosion.
- Revegetate exposed erodible soils as soon as possible. Seeding cut slopes and ditchlines is a very effective erosion control technique.

Silt fencing, straw or hay bales, and silt traps are maintenance-intensive, temporary construction measures and should be removed when no longer required.

## Temporary stream crossings

This discussion applies only to non-fish streams. Pilot trails (tote roads) are usually required for harvesting merchantable timber within the road clearing width. Landings should be located to minimize skidding across drainage structures. If temporary stream crossings are required, the district manager's approval must be obtained, and the crossings constructed in accordance with applicable timing windows and measures provided in writing by a designated environmental official. For construction of snow or one-season winter roads, it may be acceptable to construct crossings using snow fills with or without culverts, depending on expected flows.

To reduce adverse impacts on the stream bed and its banks, it is expected that the temporary crossing will be in the same location as that of the permanent structure. If the temporary crossing will be in a different location, a separate approval by the district manager is required as part of the overall harvesting approval.

Refer to the *Fish-stream Crossing Guidebook* for requirements for temporary crossings of fish-bearing streams.

Depending on the season the crossing is constructed and used, there are options as to the type of temporary crossings installed. These may include snow fills, fords, log bundles, and log skid or portable bridges. The structure must be able to handle peak flows during the period of time it will be in place without causing negative impacts on the stream bed. It should ensure flows are confined to the stream channel, which is particularly important where, if water escaped, it would continue down the road grade. The permanent structure is to be installed as soon as conditions permit.

Other points to consider concerning temporary crossings:

- Structures that clear-span the stream and its banks—such as portable bridges or log skid bridges—have the least chance of causing negative impacts.
- Temporary culverts with brow logs can be used to protect the culvert ends if skidding is planned.
- During periods of low stream flow, it may be appropriate to carefully place two parallel rows of boulders across the stream channel, with each row beneath the full width of the equipment tracks to provide suitable support of equipment loads.
- Logs placed longitudinally (in the direction of stream flow) across the base of the stream channel to support equipment tracks above the water level may be acceptable during low stream flow.

Temporary in-stream structures should be removed in accordance with the road layout and design and with any deactivation measures, which may include full rehabilitation of the secondary crossing.

## Ditch construction considerations

Several factors should be considered in construction of ditches so that both surface and subsurface flows do not cause excessive ditch or roadway erosion. These include ditch soil conditions, gradient, alignment, cross-section, ancillary works, ditch stabilization, and alternatives to ditching where ditching is inappropriate.

### *Ditch soil conditions*

Ditch soil conditions will influence erodibility. Finer textured, non-cohesive soils will be more readily eroded than coarser materials, or cohesive soils.

### *Ditch gradient, alignment, and cross-section*

How a ditch is configured, as shown on a plan profile and cross-sectional design, is critical to ensuring that water flow can be managed properly. Both gradient and path should be considered.

*Ditch gradient:*

- The ditch gradient is largely dictated by the vertical alignment of the road. Ideally, the gradient should be a minimum of 2% to ensure that water will flow and not pond. Lower gradients can still be effective, but may require a higher-than-routine level of inspection and maintenance.
- Under certain conditions, ponded water can lead to a saturated subgrade. This can contribute to severe roadway rutting, siltation, and possible failure of the roadway prism, as well as sediment deposition and plugging of cross-ditch culverts—negative impacts that can occur in both gentle and steep terrain.
- Ditch gradients in granular soils should be just steep enough to keep intercepted water moving to relief culverts without carrying excessive sediment.
- Steeper ditch gradients in erodible soils generally increase the likelihood of erosion and sediment transport. More frequent culvert placement and armouring should be considered.

In general, mid- and upper-slope roads require shorter ditch lengths than do valley-bottom roads, primarily because of the steeper ditch gradients and fewer well-defined stream channels on the slopes. On valley bottoms, by comparison, ditch gradients are usually gentler and downslope erosion concerns pose less of a problem. Drainage systems should be evaluated across the slope to review adequacy of flow paths created by the ditch and cross-drain network down the slope.

*Ditch alignment:*

- Abrupt water flow changes should be avoided. Sharp angles in the ditch alignment, or flow obstructions in the ditch, such as boulders or rock outcrops that can potentially deflect water into the subgrade or cut banks, can result in erosion of the subgrade or undermining of the cut bank.
- Sometimes it is necessary to carry a ditch farther than what would be ideal to limit ditch erosion, such as in areas of through cuts, or across areas of sensitive downslope soils where concentrating water could lead to small or mass failures. To limit ditch erosion, for example, it may be necessary to:
    - armour the ditch with angular shot rock
    - line the ditch with an appropriate geosynthetic
    - construct an erosion-proof check dam, or series of check dams within the ditchline, where velocity is also a concern. If not properly designed, however, check dams can create severe erosion holes below the dams and may require a high level of maintenance.
    - vegetate ditches (see "Ditch Stabilization," below).

*Ditch cross-section:*

- Ditches should be of sufficient depth and flow capacity to transport anticipated drainage flows.
- In cross-section, ditches should be sloped to a stable angle and designed to have adequate hydraulic and minor debris-carrying capacity, and should limit water velocities to prevent accelerated ditch erosion.
- Additional capacity for water flow, sloughing, and minor debris can be obtained by widening ditches.
- The ditch should be adequate to provide drainage of the uphill slope, the roadway surface, and minor debris (leaves, twigs, and small woody debris).
- U-shaped ditches should be avoided because the almost vertical sides tend to ravel or slough, undermining the cut slope and the shoulder of the roadway.
- Ditches should have a uniform cross-section for safety and ease of maintenance. Wide ditch bottoms facilitate grading operations where side borrow methods are used.

### *Ancillary works*

The following features are associated with ditches:

**Inlet armouring** to protect the road fill from erosion as the water flows into the cross-drain culvert inlet.

**Inlet basins** are depressions dug at the inlet of cross-drain culverts. They are intended to trap material that could, over time, restrict the intake flow or infill and plug the culvert. Properly installed, inlet basins can reduce maintenance frequency. They are required where fine-grained sediments are anticipated from ditch erosion or minor sloughing, and where woody debris movement is expected along ditches in harvested openings.

**Sediment settling ponds** differ from ditch inlet basins in that they are designed to allow sediment to settle for later removal. They are generally located downslope of the roadway, but in some instances may be incorporated into sections of ditchline. They are effective only under low-velocity water conditions. The configuration and depth of settling ponds should be adequate to allow sediment to settle and to facilitate cleanout. The backslope of unstable settling ponds can be armoured with placed shot rock or stabilized with placed large boulders.

Settling ponds are a temporary measure to protect water quality during construction. If designed for long-term use, access is required to facilitate routine maintenance. Ponds may be vegetated to assist filtering sediments.

**Ditch blocks** are installed to direct flows into the culvert inlet. They are constructed of erosion-resistant material, with the crest being approximately 0.3 m lower than the adjacent road grade. This elevation difference is critical because if the culvert becomes plugged and the water rises above the ditch block, then the flow will continue down the next section of ditchline rather than being directed onto the roadway surface.

Where ditches converge, ditch blocks are not required.

**Take-off or lateral ditches** are constructed leading away from the culvert outlet to ensure there is a positive flow away from the roadway. Their design should be in keeping with existing drainage patterns, to ensure that the flow is dissipated or controlled.

A take-off or lateral ditch is required where a minimum grade is needed to ensure that water will carry fines away rather than depositing them at the culvert outlet and restricting normal flow.

Where it is neither practical nor environmentally sound to disperse ditchwater immediately before the ditch reaches a stream, and where sediment transport is anticipated, the construction of a check dam, settling pond, silt fence, slash filter windrow, or other sediment catchment device should be considered. These sediment catchment facilities require routine maintenance to be effective.

Ditchwater should be dissipated through cross-drain culverts and a vegetated filter zone before the flow can reach a stream. Care should be taken to select an outflow location that will not destabilize the gully sidewalls and so create a larger sediment source.

### Ditch stabilization

In addition to armouring ditches with shot rock or lining them with a geosynthetic, other options are available to minimize ditch erosion.

- In erodible soils, the ditchline can be seeded or an anti-wash vegetation fabric installed. This can be very effective under low-velocity flow conditions and on soils that are erodible, and it usually helps to establish grasses. In erodible soils, it may be necessary to widen the ditch, as well as slope the sides more gently than normal.
- In some cases, polymer stabilizers (soil binders) can be sprayed within the ditchline. The manufacturer's assurance should first be obtained that use of the stabilizer will not result in adverse impacts, such as leaching, on stream water quality.
- If soils upslope of the ditchline are sensitive, then ditchline erosion treatments can be incorporated at the same time. The prescriptions may or may not be identical.
- In rare situations where the stabilization options described above do not work, consideration could be given to armouring.
- It is important that grader or other machine operations do not disturb the ditchline stabilization measures. Should this occur, the ditch should be re-stabilized as soon as practicable.

### Alternatives to ditching

In some instances, ditches may be inappropriate:

- on sites where there is a need to minimize bench cuts for stability or economic concerns (e.g., to reduce the volume of blasted rock)
- on sites where there is a need to minimize the amount of site degradation
- on ridge or hilltop roads where natural drainage occurs
- along one-season winter roads.

Nevertheless, cut slope and roadway drainage should still be accommodated in the above situations, with the use of:

- subdrains (such as French drains) in place of ditches
- French drains in place of ditch relief culverts
- road surface drains such as dips and swales
- road insloping or outsloping
- open-top ditch relief culverts
- erosion-resistant surfacing.

## Cross-drain culvert location

How far water should be carried in a ditch before being dissipated away from the road prism depends on: water volume and velocity, soil types, hillslope aspect, elevation, vegetation, rainfall intensity, the incidence of rain-on-snow events, and downslope conditions. With so many factors influencing placement of cross-drain culverts, it is not recommended that spacing tables be used unless the designer has experience and augments the tables with consideration of site-specific conditions.

Typical locations for cross-drain culvert placement are:

- at the top of a steep gradient—the intent is to prevent accelerated ditch, subgrade, or cut bank erosion by dispersing ditchwater before its volume and velocity increase downgrade
- at seepage zones
- at zones that have localized overland flow with no defined channels—it is critical to ensure that ditchwater is dissipated at the downgrade side of these zones—otherwise water flow will carry on to the next segment of the ditch, thereby increasing the flow at the start of the next section of ditchline and increasing the potential for erosion and natural drainage pattern disruption
- at any location where accelerated ditch erosion could potentially begin—again ditchwater volume and velocity should be dissipated to prevent build-up and the risk of adverse impacts on improvements and other resources
- at low points in the road profile
- where ditchline bedrock approaches the elevation of the finished grade
- immediately prior to sections of cut slope instability or ravelling
- prior to large through cuts that may be drainage divides
- at any other location found necessary during construction, or evident during maintenance inspections.

Cross-drain culverts and ditches at switchbacks often need site-specific consideration.

For forest road construction, unless soil and runoff conditions require increased sizes, recommended minimum pipe culvert diameters are 400 mm for dry sites and 600 mm for wet sites. The culverts addressed here have a design discharge of less than 6 $m^3$/sec and a diameter of less than 2000 mm. Culverts larger than this must be designed by a professional engineer. Refer to Chapter 2, "Design and Construction of Bridges and Stream Culverts" for more information.

## Cross-drain culvert installation

Proper installation of cross-drain culverts—regardless of the material used—is critical to ensuring that road stability will not be compromised by ineffective drainage.

- To prevent drain water from being directed over erodible fills, construct settling ponds adjacent to every cross-drain culvert.
- Make culverts long enough to ensure that the inlet and the outlet cannot become blocked by the encroachment of road embankment fill.
- Protect unstable or erodible fill at culvert outlets with flumes or other erosion-resistant material, and protect inlets to prevent scour and erosion.
- Install cross-drain culverts at a gradient of 1–2.5%. Shallower gradients may allow silt to build up inside the pipe. If the gradient needs to be steeper than this, consider providing outlet protection.
- To encourage smooth entry of ditch flows, skew cross-drain culverts to the perpendicular to the road centreline, by 3 degrees for each 1% that the road grade exceeds 3%, to a maximum of 45 degrees.
- Excavate unsuitable materials beneath the pipe and replace them with suitably compacted fill to provide a firm and uniform foundation.
- Install seepage barriers or collars where necessary.
- Remove large rocks or ledges and replace them with suitably compacted fill before the pipe bedding is prepared.

## Backfilling and compaction around pipe culverts

The ability of a pipe to maintain its shape and structural integrity depends on correct selection, placement, and compaction of backfill materials, and adequate depth of cover for the pipe material selected.

The likelihood of a culvert failure increases with a lack of adequate compaction during backfilling. Consideration should be given to suitably compacting the culvert backfill during installation, especially for 1200 mm pipes and larger. In general, the procedures below should be followed:

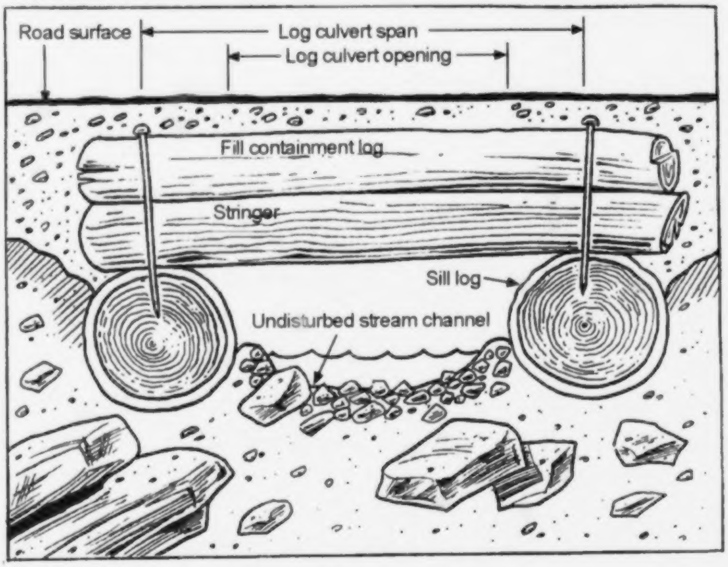
- Select good backfill material.
    - A granular non-saturated backfill material should be used. Pit-run gravel or coarse sands are usually satisfactory.
    - Cohesive materials may be used as backfill material if careful attention is given to compaction at optimum moisture content.
    - Avoid placing large angular rock, boulders, snow, or ice within the backfill material.
- Ensure adequate compaction under haunches.
- Maintain an adequate width of backfill.

- For culverts 1200 mm and larger, place backfill material in layers of 150–200 mm.
- Balance the fill height on either side as backfilling progresses.
- Compact each layer before adding the next layer.
- Adequate compaction will help to maintain the manufactured shape and help minimize cross-sectional deformations.
- Do not permit construction vehicles or equipment to cross the structure until the minimum allowable depth of cover has been placed.

## Log culvert design

A log culvert is a log structure having a span of less than 6 m between bearing points and an abutment height (if constructed as a log crib) of less than 4 m measured between the underside of the lowest crib log to the underside of the stringers.

Elevation view



Notes:

- Opening size: must pass peak flow for 100-year return period plus minor debris.
- Road width: varies with road curvature.
- Log culvert length (as measured parallel to stream): varies with road width, height and type of fill, culvert gradient and skew.
- Sill logs: place outside stream channel and below scour level; species can vary. Minimum diameter should be about 300 mm; long enough to support stringers, fill containment logs, and road fill.
- Non-woven geotextile (filter cloth)
- Stringers (puncheon): match in diameter and taper, and be free of decay and excessive crook or sweep; spiral grain should be less than 1 in 8. Knot size in middle should not exceed 125 mm. See Table 8 for sizing.
- Fill containment logs: minimum diameter 400 mm. See Figure 20. If lashing is used, inset the cable to protect it from damage by road maintenance equipment.
- Connections:
  - stringers to sill; 12 mm spiral drifts
  - fill containment log to sill: 19mm spiral drifts or four wraps of 19 mm diameter 6 × 9 fibre core wire rope.
- Inlet control: place shot rock to protect against fill erosion below the design flood level.
- Outlet control: place rock as required to prevent outlet scouring and undermining of the sill logs.
- In the case of a skewed log culvert, the span of the stringers for design purposes is measured from bearing to bearing along the stringers and not at right angles to the sill logs.

**Figure 19.** Simple log culvert.

Log culverts are used, for example:

- for streams where other resource agencies require the stream banks or stream bed to be undisturbed
- on steep-gradient streams.

Where the planned service life of the road is less than the life expectancy of the crossing components, log culverts may be used:

- as temporary structures on tote roads or pilot trails
- on short-term, or permanent, roads where ongoing minor debris problems are anticipated
- on permanent roads as temporary drainage structures at the clearing or subgrade construction stage, until the permanent drainage structures are installed.

Each log culvert design should address the following:

- opening size for design flow and debris management
- culvert length and fill and surfacing requirements
- superstructure design (stringer or puncheon sizing)
- substructure design (sills, mud sills, and foundation logs)
- inlet and outlet protection requirements.

## *Log culvert opening size*

All log culverts for streams must be designed to pass the 100-year return peak discharge and should be situated so that the structure, including its sills, is outside the design flood level. To determine this value, refer to "Estimating design discharge for streams" in Chapter 2, "Design and Construction of Bridges and Stream Culverts."

In addition to passing the $Q_{100}$ peak discharge, log culverts should be designed to manage anticipated debris. Options may include, but are not limited to:

- increasing the opening size—height, width, or both
- allowing debris to pass over the approaches
- trapping debris with a specially fitted trash rack or other device
- combining these and other options.

Debris catchment devices should be inspected frequently and cleaned as required. This aspect of the design is a site-specific consideration and may require professional input. Debris problems may be identified from terrain hazard maps, air photo interpretations, field investigations, and reports for the area. Use of the *Gully Assessment Procedure Guidebook* is recommended.

The convention for specifying the opening size (inside measurements) of a log culvert is height (vertical distance between the deepest point along the channel floor and the soffit of the stringers) followed by width (horizontal distance measured at right angles between the inside face of the sill logs).

## *Log culvert length*

Culvert length, as measured in the direction of the stream or watercourse, is determined by considering the following:

- road width
- depth of road fill over the log culvert, and fill slope angles
- type of fill over the log culvert
- inlet and outlet treatments
- culvert gradient
- culvert skew.

### Road width

If the culvert is located within a horizontal curve, extra road width to accommodate side tracking of logging trucks and hence additional culvert length is required. The required width can be found in Table 2 in Chapter 1, "Road Layout and Design."

### Depth of road fill

Use of deep road fills on top of the log stringers is not recommended. Should a failure occur, there is a potential for large volumes of sediment-producing materials to enter the stream channel. Measures to reduce road fill depth include:

- use of a longer span culvert, or a bridge for V-shaped channels
- increasing the culvert height, by use of log cribs
- relocation of the road to a more suitable crossing.

Log culverts requiring road fill depths greater than 2 m should be reviewed by a professional engineer, and deactivation plans should address fill removal measures that prevent material from entering the stream's wetted perimeter. Log culverts should be sufficiently long to contain the fill and prevent material from entering the stream. As the fill height increases for a given roadway width, so should the culvert length.

Road fill containment measures should be incorporated into the design. This can be achieved by making the culvert extra long (at least 1 m per side beyond the toe of the road fill), and securing a large containment log (at least 400 mm diameter) at the toe. See Figure 20.

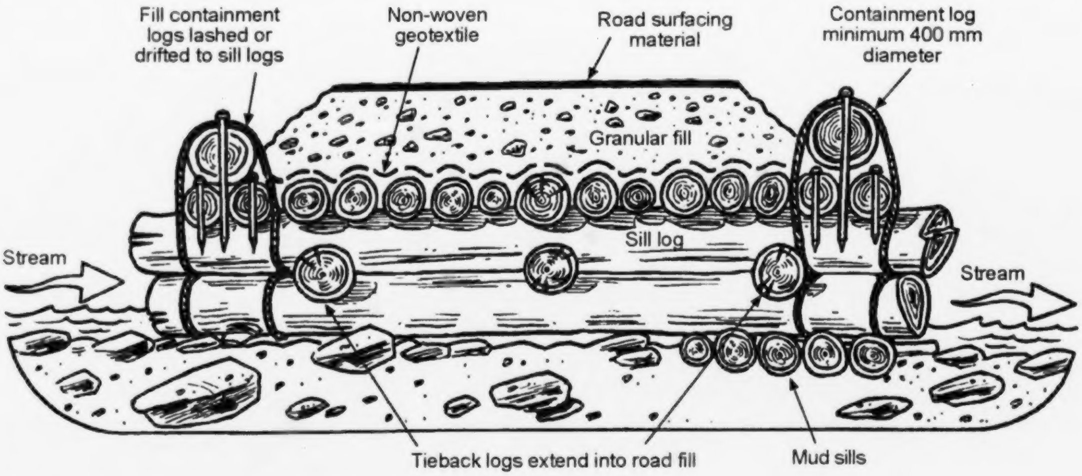

Fill containment logs lashed or drifted to sill logs
Non-woven geotextile
Road surfacing material
Containment log minimum 400 mm diameter
Granular fill
Sill log
Stream
Stream
Tieback logs extend into road fill
Mud sills

**Figure 20.** Fill containment for log culvert.

In addition, the design should include provisions that prevent road fill materials from encroaching on the 100-year flood level. For fills up to 1 m thickness, the sill logs—providing they are long enough—will serve this purpose. For higher fills, other site-specific measures should be incorporated into the design.

## Type of road fill

To maximize fill slope angles and minimize culvert length, fill over a log culvert should be shot rock or granular pit-run material. Use of silty and clayey materials should be avoided because these (1) require flatter fill slope angles (and therefore longer slope lengths) to maintain fill slope stability, and (2) increase the potential for sedimentation.

## Log culvert gradient

For stream gradients less than 10%, it is standard practice to place the stringer soffit (culvert soffit) at 0% grade or at or near the same gradient as the stream. Should the proposed stringer installation gradient exceed 10% (**culvert** soffit gradient, not the **stream** channel gradient), other structural considerations may apply.

## Channel gradients less than 10%

A cross-sectional sketch of the culvert and the fill, and a profile of the stream bed, provide the best tools for determining log culvert length. The required length can be directly measured from a sketch drawn to scale.

### Channel gradients greater than 10%

Again, the preferable method is to measure the length directly from the cross-sectional sketch for the stream.

### Inlet and outlet treatments

Headwalls or sill logs may be incorporated into log culvert design, allowing vertical end fills and therefore reduced culvert length.

### Length for skewed culverts

Where a culvert crosses the roadway at other than a right angle to the road centreline, allow for the increased culvert length caused by this skew.

## *Log culvert stringer selection*

Stringer sizing involves selection of the appropriate log diameter and species to be used for the stringers (puncheon). Table 8 presents stringer sizing for log culverts, as a function of span (see Figure 19), total fill depth, logging truck axle loads (e.g., L75), and log species. In Table 8, which was developed by professional engineers, the total fill depth is the combined thickness of road surfacing and underlying road fill materials that extend down to the top of the stringers. The total fill depth ranges from a minimum of 300 mm to a maximum of 2 m. The log diameters given in Table 8 are to be considered as minimum mid-diameters, which are measured at mid-span under the bark.

Use of oversize logs is encouraged to account for unseen flaws, to give added strength for overloads and general heavy use, and to extend the service life of the structure. For maximum service life, it is recommended that sound western redcedar be used. Fill containment logs are required to contain the fill or road surfacing and can be structural or non-structural. A geosynthetic should first be placed over the puncheon to prevent surfacing or fill material from migrating between the stringers and into the watercourse.

**Table 8.** Log culvert stringer sizing table—log diameters are mid-diameters, in millimetres.

| Span (m) | Total Fill Depth (m) | L60 D.Fir/ Larch | L60 Other | L75 D.Fir/ Larch | L75 Other | L100 D.Fir/ Larch | L100 Other | L165 D.Fir/ Larch | L165 Other |
|---|---|---|---|---|---|---|---|---|---|
| **1.5** | **0.3** | *250* | *250* | *250* | *275* | *250* | *325* | *350* | *450* |
| | **1.0** | *250* | *250* | *250* | *225* | *225* | *250* | *250* | *300* |
| | **2.0** | *250* | *250* | *250* | *250* | *250* | *250* | *250* | *275* |
| **3.0** | **0.3** | *350* | *425* | *375* | *475* | *400* | *475* | *650* | *800* |
| | **1.0** | *250* | *300* | *275* | *300* | *275* | *325* | *350* | *400* |
| | **2.0** | *250* | *325* | *275* | *325* | *300* | *350* | *375* | *450* |
| **4.5** | **0.3** | *460* | *575* | *500* | *625* | *575* | *675* | *700* | *825* |
| | **1.0** | *325* | *400* | *350* | *425* | *375* | *475* | *500* | *600* |
| | **2.0** | *375* | *425* | *400* | *475* | *425* | *475* | *525* | *625* |
| **6.0** | **0.3** | *550* | *675* | *600* | *725* | *650* | *775* | *800* | *950* |
| | **1.0** | *425* | *525* | *450* | *550* | *500* | *575* | *600* | *750* |
| | **2.0** | *475* | *575* | *500* | *625* | *525* | *650* | *625* | *825* |

**Notes:**

1. Other refers to cedar, spruce, lodgepole pine, jack pine, and hemlock.
2. Sizes are based on sound logs, with no allowance for decay.
3. Logs should be free of cracks, excessive taper, sweep, damage, or large knots.
4. Reverse the taper of adjacent logs.
5. Spans over 3 m should be lashed at mid-span.
6. Logging truck axle loads in accordance with B.C. Ministry of Forests standards.
7. Axle loads allow for unbalanced 60%–40% wheel loading.
8. Fill depths greater than 2 m should be designed by a professional engineer, or designed from tables prepared by a professional engineer.

## *Log culvert substructure design*

The substructure required depends on the bearing capacity of the foundation soils and the length and diameter of the logs available. Choice of substructure requires first an estimate of the bearing strength of the soil at the site. From this, the size (diameter and length) of the logs needed to support the design loads can be determined. Refer to FERIC's *Log Bridge Construction Handbook* (1980) for a detailed explanation of this topic.

### Single sill logs

Single sill logs may be used as culvert foundations if the ground is firm and the sill log provides sufficient clearance for the design flood and debris passage. The minimum diameter for sill logs should be about 300 mm. For short service-life culverts (planned for less than 3 years use), almost any species of wood will suffice for the sill logs, provided it is sound throughout.

The expected service life for sill logs is as follows:

- Cedar (sound, with preservatives applied to cut surfaces): 20 years plus
- Douglas-fir: 8–10 years
- Spruce, hemlock, and balsam: 4–6 years
- Hardwood species: Variable but probably less than 4 years

### Mud sills

If the natural ground will not support the culvert loads on a single sill log, the load-bearing area can be increased with the use of mud sills. These are short logs, 250 mm (or larger) in diameter, and 1–6 m in length, placed at right angles under the sill log for the entire length of the sill.

For crossings on soft ground, on non–fish-bearing streams, another option is to extend the mud sills completely across the channel to and beneath the other sill log. This increases the stability of the structure. It is important that the mud sills be placed below the scour level.

## *Log culvert inlet and outlet protection*

### Inlet and outlet protection for stream culverts

Inlet and outlet protection for stream culverts is not normally required because the sill logs are placed outside the stream channel and bedded below scour level. If there is a concern about erosion around the inlet or outlet, any erodible surfaces should be protected with rock to a level equivalent to the design flood. Some sites may require a settling or debris catchment basin at the inlet. Such features should be individually designed.

### Inlet protection for cross-drain culverts

Inlet protection for cross-drain culverts will normally be achieved with a ditch block to ensure that ditchwater is directed into the log culvert and not past it. In most cases, a catch basin is required to trap sediment and debris. For cross-drain culverts on a steep road grade, lining the ditch block, catchment basin, and bottom of the channel with rock may be necessary to minimize scouring.

### Outlet protection for cross-drain culverts

Log culverts should not be placed on top of erodible fills. It is preferable that ditch flows are directed onto erosion-resistant areas, or onto outlet protection such as flumes or rip rap aprons. Ditch water flows should never be directed onto unprotected sidecast material unless it is composed of rock or other erosion-resistant materials. On steeper slopes, erosion control at the culvert outlet is a design challenge. One option is to provide extensive outlet protection down the slope to an erosion-free area.

### *Open top log culverts*

Open top culverts, constructed of logs, may be used to control road drainage on steep road grades or in situations where plugging of culvert inlets is a chronic problem.

## Log culvert construction

Proper log culvert construction requires experience, skill, and good workmanship. Before construction begins, the crew should be made familiar with any particular installation requirements, including any design drawings. Construction should be in accordance with requirements of the "Log culvert stringer selection" and "Log culvert substructure design" sections above. In addition:

- The location of the substructure should be marked on the ground before and after the site-clearing operation. Re-establishing the road centreline may be necessary.
- For those log culverts with high fills or requiring skewing, it is important that the sill logs be cut to the correct length and placed in the proper position.
- Two evenly sized sill logs should be laid parallel and clear of the wetted perimeter of the stream, and should have solid bearing.
- The sill logs should be carefully bedded below the scour depth of the stream. If scouring is anticipated, a trench should be excavated below the scour level for the sill logs. Constructing a non-erodible foundation pad of large angular shot rock is a suitable alternative.
- The sill logs and stringers should be solid, good-quality wood, sized according to the design drawings or the stringer sizing table found in Table 8. Peeling the logs will normally extend their service life. For short-term roads, use of species that provide only a short service life is acceptable, provided the logs are structurally sound.
- A layer of non-woven geotextile filter cloth should be placed over the stringers.

The outside stringers should be pinned to the sills with drift pins or lashed to the sill log, or they should be placed in neat daps made in the sill log, and drift pinned, to prevent any shift or spreading of the stringers while the culvert is being backfilled. Avoid sharp daps, which will result in high stress concentrations, or slabbing the stringer ends, which will degrade shear load capacity.

## Ford design and construction on non-fish streams

A ford is a dip in a road constructed to facilitate crossing a stream. The objective of a ford is to maintain drainage and provide a safe, erosion-free, and storm-proof crossing that requires little or no maintenance. In the past, inappropriate location and design of fords, and uncontrolled use, has led to a number of negative environmental impacts. These include increased sediment delivery to streams, and degraded water quality downstream.

In isolated locations where maintenance equipment may not be available on a continuing basis, properly designed and constructed fords require little maintenance, are storm-proof, and can be effective in reducing adverse impacts in drainage systems that are prone to debris torrents (Figure 21). Fords may also be considered for areas of low traffic and intermittent use. They should be considered as alternatives to bridges or culverts only where the crossings will not result in negative environmental impacts and where traffic use is confined to low-flow periods. A ford would not normally be considered if the crossing is expected to be subjected to extensive or year-round traffic.

### *Ford planning*

Fords should be identified in the planning stage of road development to ensure that the required design and measures will include appropriate road grades leading into and out of the stream crossing.

- Prior to planning a ford, the stream should be evaluated to ensure that it is not a fish stream. Refer to the *Fish-stream Crossing Guidebook* for limitations on the use of fords on fish streams.
- When planning a ford, and establishing design criteria, determine if any of the following possible user safety restrictions (or combination of restrictions) will apply to the stream crossing:
  - the design vehicle will be able to cross the ford only during certain months of the year
  - the design vehicle will not be able to cross the ford during periods of specific maximum stream flows
  - only certain types of vehicles will be able to cross the ford
  - only certain specific road uses will be considered (such as industrial use only).

Each proposed ford design is unique, but the objectives of any design are to:

- pass the design peak flow
- minimize downstream erosion of the stream
- prevent sediment input into the stream from the approaches and associated ditches

- provide a suitable road profile to accommodate safe passage of the design vehicle
- ensure that the stream remains in its channel and cannot be diverted down the road or ditches
- ensure that the ford will either pass channel debris—the preferable option—or trap it

Non-standard crossing situations may require installation of weirs and other energy-dissipating structures upstream and downstream. Under these situations, design by a professional engineer, and agency consultation, may be required.

## *Ford design*

For a ford, the road profile should dip into and out of the stream, creating a concave shape sufficient to ensure that the stream cannot be diverted away from its natural channel and down the road.

- Ensure that the anticipated design vehicle can negotiate vertical curves at the proposed ford. Where it is practical to do so, approaches should be at right angles to the stream.
- Check the debris flow history of the stream channel
  - on air photos
  - on terrain stability maps or terrain stability field assessments
  - in the field.

For further information, refer to the *Gully Assessment Procedures Guidebook*.

- If there is a debris flow problem, decide whether the ford should be designed to:
  - trap the debris, or
  - allow the debris to pass over the ford—the preferred option. If the debris is to be trapped, specialist consultation may be required to size the catchment basin.

The size and shape of the largest cobbles or boulders in the stream channel indicates the minimum size of rock required to resist movement when the stream is in flood, and thus provides a guide to the minimum size of rock to be used to construct the ford. The more angular the rock (such as shot rock), the more resistant it will be to moving.

In some situations, the use of a ford may be restricted to low-flow periods when the flow is subsurface. A low-flow culvert can be designed and installed to pass the anticipated low flow. With this design, peak flows and debris would flow over the top of the ford and some increased annual maintenance may be necessary. The running surface material should be of a size to resist erosion.

Design methods are available for determining flow rates through voids in rock fills. Such voids may plug, so the dip in the road profile should be designed to accommodate the $Q_{100}$ peak flow, plus any anticipated debris.

### Design approval requirements

Sketches of the ford design should be prepared, showing:

- the road profile, extending at least 50 m at each end beyond the wetted perimeter at $Q_{100}$ peak flow
- the width and depth of the wetted surface during:
  - those months when use of the road is anticipated
  - $Q_{100}$ peak flow level and an estimate of debris volumes to be passed or trapped
  - annual low-flow level, or the flow levels for the periods of anticipated use
- the range and average size of the material in the stream channel and its shape (angular, semi-angular, or rounded)
- the minimum width of the road running surface required to accommodate anticipated traffic
- the requirements for any erosion-resistant materials for the road running surface, such as shot rock and concrete cross-ties, including use of any geosynthetics, to help separate different types and gradations of road fill materials
- the rock source, size, and volume requirements
- the length, width, and depth of the upstream catchment basin if one is proposed
- the type and dimensions of the low-flow culvert, if one is proposed
- the length of apron to be surfaced with erosion-resistant material.

## *Ford construction*

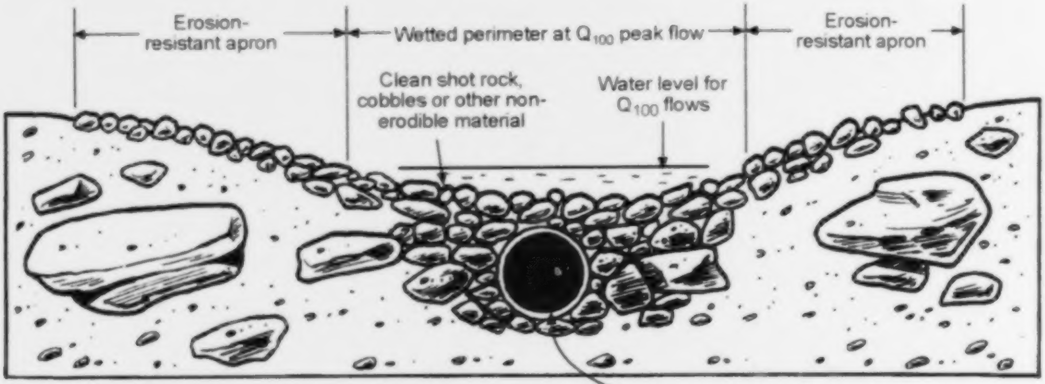
For low-flow streams, or for those that are dry in the summer, a properly designed and constructed ford should allow the stream flow to pass around and between the subsurface rock. For this, place the larger-size rock across the base and lower portion of the ford cross-section. For perennial streams where appropriate rock sizes are unavailable, consider the following alternatives:

- Construct a broad catchment basin, or upstream weirs, to slow the stream flow velocity and thus reduce the size of rock required for the ford to resist the erosion forces.
- For steeper-gradient streams, build up the downslope portion of the ford by positioning log cribs, gabions, lock blocks, etc. to contain the rock fill for the ford. In most situations, this will flatten the stream gradient at the crossing, thus reducing the stream velocities and permitting the use of smaller-size rock.

To prevent sediment delivery where approach drainage cannot be directed away from the stream, and to prevent sediment tracking by equipment and vehicles, the following procedures should be considered:

- armouring ditches with non-erosive material
- directing runoff into sediment basins or other sediment trapping device
- capping the road surface with erosion-resistant material on either side of the ford for an appropriate distance to protect the road and minimize sediment delivery to the stream.

**Road profile (stream cross-section)**


Erosion-resistant apron
Wetted perimeter at $Q_{100}$ peak flow
Erosion-resistant apron
Clean shot rock, cobbles or other non-erodible material
Water level for $Q_{100}$ flows
Low-flow culvert (optional)

Note: Road profile must have sufficient depth to ensure stream flows cannot breach the ford and run down the road or ditch.

**Road cross-section (stream profile)**

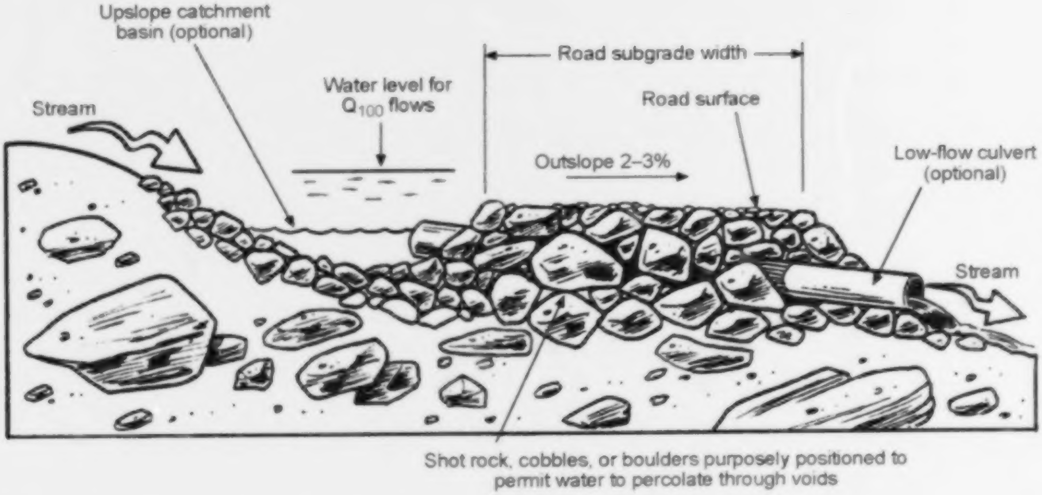

Upslope catchment basin (optional)
Road subgrade width
Water level for $Q_{100}$ flows
Road surface
Stream
Outslope 2–3%
Low-flow culvert (optional)
Stream
Shot rock, cobbles, or boulders purposely positioned to permit water to percolate through voids

**Figure 21.** Plan and profile of a ford crossing.

### Ford operating constraints

Once a ford is constructed, its use should be controlled to ensure that the integrity of the structure is maintained and that any potential adverse impacts on the environment are minimized.

- Nothing that could destroy the running surface of the ford should be dragged or skidded across it.
- Vehicles using the ford should be in good working order and not leaking fuel, hydraulic fluids, lubricating oil, or cargo.
- All excess soil should be removed from heavy equipment before it crosses a watercourse.
- The ford should not be used if the water depth is greater than the axle height of the vehicle. It may be appropriate to install a water-depth gauge clearly visible from the road.
- Should a ford become unsafe for traffic during high water, measures should be taken to warn and exclude users for that period.

### Ford maintenance

Properly designed and constructed fords are usually low maintenance, storm-proof structures. Nevertheless, the following activities may be required:

- Fords should be inspected at a frequency commensurate with the risk to users.
- Running surfaces, approach grades and aprons, ditches, and catchment basins should be properly maintained.

## Suggestions for further reading

American Iron and Steel Institute. 1991. *Handbook of Steel Drainage and Highway Construction Products*. Canadian edition. W.P. Reyman Associates, Inc. New York, N.Y.

British Columbia Ministry of Forests. 2002. *Fish-stream Crossing Guidebook*. Victoria, B.C.

____________. 2001. *Gully Assessment Procedure Guidebook*. Victoria, B.C.

____________. 1999. *Forest Service Bridge Design and Construction Manual*. Victoria, B.C.

Nagy, M.M., J.T. Trebeth, G.V. Wellborn, and L.E. Gower. 1980. *Log Bridge Construction Handbook*. Forest Engineering Research Institute of Canada (FERIC), Vancouver, B.C.

# 5. Road and Structure Inspection and Maintenance

## Introduction

Forest road and bridge inspection and maintenance involves the following activities:

- assigning road inspection priorities based on risk analysis
- road inspections
- bridge and major culvert inspections
- road prism maintenance
- structural maintenance of the subgrade
- clearing width maintenance
- ditch and culvert maintenance
- road surface maintenance
- maintenance of structures
- inspection and repair of deactivated roads.

Required maintenance activities should be determined from field information documented during formal inspections, and from information and incidents provided by road users. From this, a maintenance plan should be prepared to remedy the identified deficiencies.

The objectives of forest road maintenance are:

- ensuring user safety
- minimizing potentially adverse effects to adjacent forest resources from the use of the road
- maintaining safe fish passage at fish stream crossings
- maintaining water quality in community watersheds
- protecting the road infrastructure investment.

Road works shutdown indicators and procedures should be considered when forest road maintenance works are being carried out on active roads and when remedial works are being carried out on deactivated roads. These indicators and procedures are provided in Chapter 3, "Road Construction."

## Assigning road inspection priorities

A person responsible for carrying out inspections on maintained roads and temporary and semi-permanently deactivated roads should "risk rate" roads using a simple, qualitative risk-analysis procedure.

Risk of damage to elements at risk = Hazard × Consequence

Assign maintenance inspection priorities based on the level of risk to elements at risk. Determine qualitative risk ratings (e.g., VH, H, M, L, VL) according to a combination of ratings for hazard and consequence, and then assign maintenance inspection priorities. Usually, roads that present the highest risk of damage to elements at risk also receive the highest inspection priority and frequency of inspection.

Table A10.1 in Appendix 10 is an example of a qualitative risk matrix. It combines a relative hazard rating and a relative consequence rating. Table A10.1 presents an example 5×3 matrix for landslide risk analysis, but a different qualitative method of risk analysis that uses a 3×3 matrix (three qualitative ratings for hazard [H, M, L] and three qualitative ratings for consequence [H, M, L]) is often satisfactory for assigning inspection and maintenance priorities.

Hazard, for assigning inspection priorities based on risk, is the likelihood of a particular condition with the potential for causing an undesirable consequence. Hazard events may include accelerated or uncontrolled soil erosion and sediment transport, slumping or sliding, or deterioration of structural elements within the road prism. These events may be caused, for example, by cut and fill slope failures, shoulder slumps, washouts, blocked ditches and culverts, road surface erosion, damaged guide rails or curbs on bridges, filled-in cross-ditches on deactivated roads, and events related to weather.

Consequence is the product of the element at risk and the vulnerability of that element at risk from hazard events described above. The term "vulnerability" refers to the fact that an element at risk may be exposed to different degrees of damage or loss from a hazard occurrence.

Tables A10.3–A10.11 in Appendix 10 are examples of landslide consequence tables that express consequence in terms of three relative qualitative ratings: H, M, and L. These tables, either in whole or in part, or some modified form of these tables as required to reflect specific road and site conditions and elements at risk, may be useful in determining consequences for the purpose of assigning inspection priorities based on risk.

The elements at risk included in these consequence tables include:

| Table | Element at risk |
|---|---|
| Table A10.3 | Human life and bodily harm |
| Table A10.4 | Public and private property (includes building, structure, land, resource, recreational site and resource, cultural heritage feature and value, and other features) |
| Table A10.5 | Transportation system/corridor |
| Table A10.6 | Utility and utility corridor |
| Table A10.7 | Domestic water supply |
| Table A10.8 | Fish habitat |
| Table A10.9 | Wildlife (non-fish) habitat and migration |
| Table A10.10 | Visual resource in scenic area |
| Table A10.11 | Timber value (includes soil productivity) |

Refer to "Slope stability considerations," in Chapter 1, "Road Layout and Design," and to Appendix 10 for further general information on risk analysis.

When planning inspections and maintenance activities at fish stream crossings, refer to the *Fish-stream Crossing Guidebook*.

## Road inspections

Inspections should focus on the structural integrity of the road prism, drainage systems, road surface, and sediment control. An inspection plan should be prepared based on inspection priorities assigned as a result of a risk assessment.

It is recommended that, as a minimum, all active roads receive one documented inspection per year. Roads should also be inspected following severe storms, before winter, and after the spring freshet.

After extreme weather events, inspections should be carried out as soon as possible. Aerial inspections, where adequate information can be obtained to determine a course of action, are acceptable. Culverts constructed or modified on fish-bearing streams after June 15, 1995, should be inspected to ensure continued provision of safe fish passage.

Inspection results should be recorded in a format that enables ready access for future reference. All staff who travel on forest roads are encouraged to report any road maintenance problems that they encounter in the course of their duties.

## *Road inspection records*

Inspection records should cover key road elements and any deficiencies noted. Where major problems are identified, it is recommended that photographs be taken to accompany the inspection records. A sample road inspection and maintenance report is provided in Appendix 6.

The items to be assessed and evaluated when an inspection is carried out include:

- user safety
- structural integrity of the road prism and clearing width
- drainage systems
- potential for transport of sediment from the road prism
- road and bridge surfaces
- safe fish passage at stream crossings.

On completion of inspections, a maintenance plan should be prepared and maintenance works prioritized in accordance with risk. Inspection reports and maintenance records should be retained on file for review at the request of the district manager and for forest practice audits. Review of past reports and records can also assist forest road managers in identifying recurrent problems and identifying those road sections to be assigned a higher risk rating.

## *Remedial works*

After a road inspection is completed, any deficiencies found must be remedied by the earliest of the following:

- a time period that is commensurate with the risk to the road, its users, and the environment,
- a time specified in the inspection report prepared by that person, or
- a time determined by the district manager.

The time frame for remedial action can and should be specified in the inspection report. "Reasonable time" will vary according to the specific site and problems identified. For example, waiting until equipment is in the area is inappropriate where the road fill is already failing into a stream. However, it may be appropriate to wait for equipment where a ravelling cutslope is filling in a ditch that has a low risk of transporting sediment to a stream.

# Bridge and major culvert inspections

## *Bridge inspections*

Bridge inspections can be broadly categorized into two types: routine condition inspections and close proximity inspections.

### Routine condition inspections

Routine condition inspections involve visual and physical (non-destructive) testing of log stringer, steel, concrete, or glulam bridge components, or major steel culverts. These inspections can be completed by qualified inspectors, which would be those having appropriate training and experience to inspect bridge and major culverts and interpret the results. Inspectors should have adequate training and experience with the type of structures that they will be inspecting in order to be able to focus their attention in the critical areas for the types of structures encountered. Interpretation of results would involve evaluating inspection results as the inspection progressed.

For example, in review of wood components, if rot is found, the inspector should able to assess the significance of the rot to the structure's integrity. An inspector should be able to develop a conclusion of the components structural integrity considering the amount of rot, component being inspected, and location or rot on/in the component for the structure being inspected. Inspectors should be able to establish whether structural deficiencies require evaluation by professional engineers or can be simply rectified by specifying suitable repairs.

### Close proximity inspections

Close proximity inspections would generally be carried out in review of complex, larger structures or where deficiencies have been noted in routine condition inspections. Typically, a close proximity inspection requires a higher level of expertise in interpretation of results as the inspection progresses. Close proximity inspections would generally involve the detailed inspection and review of primary structural components. Close proximity inspections would be carried out by a professional engineer or under a professional engineer's direct supervision.

## *Inspection frequencies*

Unless a professional engineer specifies a longer period, bridges and major culverts composed of steel, concrete, and treated timbers must be inspected at least once every 3 years by a qualified inspector, and a record of the inspection made. If portions of the structural components (stringers, girders, or substructure) are made of untreated wood, the structure must be inspected at least once every 2 years.

In addition to regular scheduled inspections, structures should be inspected after severe storm events.

### Inspection records

The inspection record of a bridge or major culvert must include all of the following:

- date of the inspection
- a condition assessment of the components of the structure
- a recommendation for any repairs that may be required and a schedule for those repairs
- the date of the next scheduled inspection
- the length of time a bridge has been at its current site
- a note about whether a bridge was designed and constructed to be at the current site for no more than 15 years.

Inspection records for major bridges and culverts must be retained for 1 year beyond the actual life of the structure at the site. Should a structure fail, these records will be useful in any subsequent investigation. These records can also be used as a reference to determine the type of structures that are cost-effective and environmentally suitable for similar stream crossings.

### Structural deficiencies noted in inspections

The sequence of identifying and correcting structural deficiencies in existing bridges is as follows:

1. A qualified inspector identifies and records possible structural deficiencies.
2. A professional engineer carries out a field review of the structure, and confirms or recommends the following, as applicable:
    - the types of work that must be carried out to correct the deficiencies, or
    - the need to protect road users by either
        - installing signs detailing the load rating prepared by the engineer, or
        - closing or removing the structure.

## Road prism maintenance

Maintenance is required to ensure user safety and stability of the road prism, and to minimize sediment transport from the road prism.

Methods to maintain the road prism include:

- stabilization of the road cut and fill slopes, repair of minor scours and washouts, and improvements of drainage systems before more serious problems occur
- removal of loose rocks, stumps, or other unstable materials (including dangerous trees) that present a hazard to road users
- seeding of all exposed soil that will support vegetation, by hydro-seeding or dry seeding, and reseeding of bare spots to fill in as required

The reasons why these problems are occurring should also be assessed and long-term corrective measures determined.

## Subgrade maintenance

Subgrade maintenance is necessary to ensure that the road system will fulfill its designed function until deactivation. Measures to consider include:

- repairing chronic soft subgrade areas and problematic frost sections by excavating and replacing the weak soils with suitable granular material, including use of geosynthetics where appropriate
- modifying the road (may require an approved road layout and design)
- replacing or repairing the running surface if the road has chronic problems with ruts, potholes, and a broken surface that renders the road unable to support design loads
- cleaning up minor slumps, rock falls, and other sites where potential hazards are evident; and implementing measures to stabilize the site
- correcting the potential failure of stream crossing approach fills.

## Clearing width maintenance

Brushing of the road clearing width should be carried out for vegetation control and to provide safe sight distances. For example, potential hazards exist where brush limits visibility at the inside of a curve or at bridge approaches, or where heavy snow loads on roadside trees may cause the trees to bend over the road surface, restricting use of the road and creating a safety hazard.

## Ditch and culvert maintenance

Ditches should be cleaned and graded as necessary. However, grass or low vegetation lining the ditches is desirable to minimize scour and sediment transport. In domestic watersheds, ditch maintenance should be limited to removing rock falls and any slumping or ravelling material, while maintaining as much grass cover or other low vegetative cover as is practicable. Care should be taken to prevent blading material over the ends of culverts or undercutting cut slopes—a practice that will reduce their stability. Ponding of water in ditches should also be prevented, as it can saturate and weaken the road subgrade and lead to surface rutting.

Ditches should be kept unobstructed by tall vegetation, so that maintenance equipment operators can see the ditches and drainage structures. Culverts are often damaged because the grader operator cannot see the culvert ends through the vegetation growing in the ditches.

Additional routine ditch and culvert maintenance operations include:

- cleaning and repairing of culverts and ancillary drainage works to provide for flow of water
- repairing inlets, outlets, ditch blocks, catch basins, and flumes
- replacing cross-drain, flumes, and rip rap
- installing additional cross-drain culverts and ditch blocks where required, usually made evident by ponding of water or erosion (scour) in the bottom of the ditches.

These activities should be carried out at a time and in such a way as to minimize the potential for stream sediment delivery.

## Road surface maintenance

### *Grading operations*

A well-graded road should be slightly crowned, with no unbreached windrows. This will facilitate storm and meltwater drainage, minimizing erosion and transport of sediment from the road surface. A crowned road, however, is not always desired, as in the case of insloped or outsloped roads.

Roads should be graded where grading will be beneficial to maintaining structural integrity or will help protect the subgrade from damage. Grading can also add to vehicle efficiency and user safety. To protect the subgrade, roads should be graded before the surface:

- reaches severe stages of wash-boarding or pothole formation, or
- begins to trap water in windrows or ruts (windrows and ruts can result in water flowing down the road, scouring the surface, and potentially causing a washout when it reaches a dip in the road).

Restoring a severely damaged road surface can be a major undertaking and may require ripping the surface to below the pothole depth and recompaction of the surface material. Road grading should take place only when moisture conditions are suitable, and not when the road is either too wet or too dry. Preferably, no windrows should remain after the final pass; at the very least, those that do remain should be breached to provide for drainage. Grading material over the banks or into ditches should be minimized, as this material may be difficult to retrieve.

### *Resurfacing operations*

Resurfacing of gravel roads is required when the existing surfacing material is no longer sufficient to support traffic loading or when there is not enough material available for grading purposes. Over time, surfacing material can break down and is lost from the road surface. Spot-gravelling of roads may be required where short sections of the road surface are failing or have a potential for failure, or where potholes that cannot be satisfactorily graded out are evident.

Information on surfacing roads is available in Chapter 3, "Road Construction."

## Structure maintenance

### *Bridges and stream culverts*

Bridge maintenance can be divided into two activities: structural and surface.

#### Structural maintenance of bridges

Structural maintenance involves repairing or replacing structural members of a bridge based on the results of inspections made by a qualified inspector. In some instances, the works will be carried out by or under the supervision of a professional engineer.

Examples of structural maintenance are:

- tightening the bolts connecting timber members
- installing shims to ensure adequate load transfer where there is loss of contact between piles, pile caps, stringers, crib timbers, needle beams, or other structural elements
- replacing stringers or girders.

#### Surface maintenance of bridges

Surface maintenance involves repairing or protecting parts of the bridges and approaches that do not directly affect structural integrity.

Examples of surface maintenance are:

- keeping the waterway opening free of logs and debris
- keeping the bearing surfaces, including plates, anchor bolts, and neoprene pads, free of gravel and dirt
- keeping wood stringers free of dirt accumulations
- resetting nails protruding from running planks
- replacing missing or damaged ties and running planks

- repairing or replacing damaged guide rails or curbs
- removing gravel build-up on concrete or timber decks.

### Stream culvert maintenance

In addition to maintenance related to fish habitat covered in the *Fish-stream Crossing Guidebook*, stream culvert maintenance is carried out to ensure that the structure maintains its capability to conduct water under the road.

Examples of stream culvert maintenance are:

- repairing damaged inlets and outlets
- repairing armouring around inlets and outlets to reduce sediment transfer, particularly in community watersheds
- removing debris blocking or obstructing culvert inlets. If removing beaver dams, the Ministry of Sustainable Resource Management should be contacted for permission and advice. Installation of beaver protection devices should also be considered.
- replacing culverts where the bottoms are rusted out and when subject to damage from water seepage
- repairing major culvert headwalls and spillways when necessary, to protect the structures and the streams.

When replacing culverts at stream crossings, refer to the *Fish-stream Crossing Guidebook* for additional information.

## *Other structures*

### Cattleguards

Clean and repair cattleguards, or replace if repair is neither practical nor cost-effective.

### Fences

Repair or replace range fences that have been damaged as a result of activities on the road. The range section in the local district office of the Ministry of Forests can advise on acceptable fence construction specifications and practices.

### Signs

Repair or replace damaged or vandalized signs and posts.

### Fords

Remove debris and sediment build-up on fords and approaches to minimize impact on downstream resources. Refer to "Ford design and construction on non-fish streams" in Chapter 4, "Road Drainage Construction," for additional maintenance information on fords.

### Weirs

Where weirs are installed in a stream to maintain water levels for fish passage, they should be inspected and maintained to ensure that the fish passage objectives are being met.

## Inspection and repair of temporary and semi-permanently deactivated roads

Inspections of temporarily and semi-permanently deactivated roads are to be carried out at frequencies commensurate with the risk to the road, its users, and adjacent forest resources. Their purpose is to assess the adequacy of bridges, culverts, and ditches, and to determine the need for further drainage work, road surfacing, and revegetation.

Where inspections identify inadequacies, remedial works must be performed to satisfy the requirements of the Forest Road Regulation.

A sample road deactivation inspection report is provided in Appendix 7.

## Suggestions for further reading

British Columbia Institute of Technology (BCIT). 1995. *Surface Maintenance*. RRET 3328. Burnaby, B.C.

____________. 2001. *Bridge Maintenance*. RRET 3324. Burnaby, B.C.

____________. 2001. *Culvert Maintenance*. RRET 3322. Burnaby, B.C.

British Columbia Ministry of Forests. 2002. *Fish-stream Crossing Guidebook*. Victoria, B.C.

# 6. Road Deactivation

## Introduction

This chapter describes the objectives of road deactivation[1] and procedures for developing and reporting deactivation prescriptions. It also presents a number of techniques to address the province-wide range of terrain, soils, climatic conditions, and access. The other aim of this chapter is to provide administrative and process-oriented guidance on how to interpret and meet the requirements of the Act and Forest Road Regulation.

Refer to the Ministry of Forests *Best Management Practices Handbook: Hillslope Restoration in British Columbia* and other suggestions for further reading for more information on the technical and operational aspects of road deactivation. The objectives of this chapter are to:

- discuss deactivation objectives and the three levels of road deactivation
- describe and illustrate some common techniques for water management and road fill pullback used to reduce potential adverse effects on adjacent forest resources, and identify the range of techniques typically employed for each level of deactivation
- discuss the methodology used to conduct deactivation studies and develop prescriptions, and describe the content of these prescriptions
- discuss the involvement of qualified registered professionals in development of deactivation prescriptions, and present the linkage between prescriptions and terrain stability field assessments
- discuss revegetation requirements for deactivated roads, major works implementation, post-deactivation inspections, maintenance, and final approvals of deactivation works.

## Objectives of deactivation

Deactivation minimizes the risk to resources—including environmental, social, and economic resources—within and adjacent to the road location from hazards such as landslides, uncontrolled soil erosion, and sediment transport.

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[1] In the Act, **deactivation** of a road is an engineering issue that involves application of techniques to stabilize the road prism, restore or maintain the natural drainage patterns, and minimize sediment transport to protect neighbouring resources at risk from potential landslide and sedimentation events. In the Act, **rehabilitation** of a road is a silvicultural issue that is typically done in accordance with a silviculture prescription or logging plan, and is normally carried out concurrently with (or following) deactivation, to restore the affected area to a productive site for growing crop trees.
**Note:** Deactivation is not necessarily tied to road closure, though that result may be unavoidable. Any administrative process to remove proponent responsibilities for the future stability of the landbase and any steps to remove legal status would take place after carrying out permanent deactivation.

Prescriptions must meet three important engineering objectives:

- stabilize the road prism and clearing width
- restore or maintain surface drainage patterns, and control subsurface drainage, consistent with natural drainage patterns
- minimize the impact of silt and sediment transport on other forest resources.

In addition, a deactivation prescription and associated works must address the following:

- Consideration must be given to the level of deactivation and the level of access that will be provided to meet the objectives for integrated resource management shown in the forest development plan.
- Deactivation works in community watersheds must not adversely affect water quality.
- Safe fish passage and protection of fish habitat immediately upstream and downstream of the crossing must be provided for or addressed, as must the timing and description of the work to achieve these objectives.
- All works in and around a stream crossing must be in accordance with the timing windows and measures that have been developed and made available by the designated environment official. If the proponent wishes to deviate from these measures, or if measures have not been made available, approval to do so must first be obtained from the district manager. Refer to the *Fish-stream Crossing Guidebook* for information related to crossings of fish streams.
- While vehicle access may be desirable, pullback of unstable fills along segments of a permanently deactivated road may eliminate such access. The focus should be on stabilizing the road prism, restoring or maintaining the natural drainage patterns, and minimizing sediment transport. The benefits of motor vehicle access should be considered, only if it will not adversely affect forest resources. There is no legal requirement for the tenure holder to provide such access if additional expenditures are necessary to do so.

## Deactivation levels

A permit holder is required to carry out road maintenance as defined in the Act until a road is deactivated, transferred to another user, or taken over by the district manager. The Forest Road Regulation describes three levels of deactivation that can be used for forest roads: *temporary*, *semi-permanent*, and *permanent*.

### *Temporary deactivation*

Temporary (or seasonal) deactivation may be used when regular use of the road is to be suspended for up to 3 years. The temporarily deactivated road must be field-inspected at a frequency commensurate with the risk to user safety and forest resources. If inspections indicate inadequate deactivation or damage to deactivation work, repairs must be made to correct the deficiencies.

### *Semi-permanent deactivation*

The intent of semi-permanent deactivation is to place the road in a self-maintaining state that will result in minimal adverse impact on forest resources during the time that regular use of the road is suspended. Similar to temporary deactivation, regular inspections of semi-permanent deactivation works are required. Identification of deficiencies should be followed by any necessary corrective measures within a reasonable timeframe, considering the risk to the road, its users, and the environment.

Temporary deactivation for more than 1 year is not permitted for roads that are located in isolated areas that are accessible only by air or water or are located in areas with a moderate or high likelihood of landslides. The reason is that less frequent inspections are likely to occur for such roads, and it would be difficult to get equipment and crews to the sites for any necessary repairs. Semi-permanent deactivation is required in these areas to provide a lower risk to user safety and adjacent environmental resources.

Semi-permanent deactivation may be used for roads that are to be deactivated beyond 3 years or as described above for roads in isolated areas. In addition to the range of measures commonly deployed in temporary deactivation, for semi-permanent deactivation greater attention should be placed on mitigating the risk to adjacent resources through more aggressive application of water management techniques and possibly road fill pullback.

### *Permanent deactivation*

The intent of permanent deactivation is to place the road in a self-maintaining state that will indefinitely protect adjacent resources at risk. Permanent deactivation commonly involves a range of measures that are similar to semi-permanent deactivation, but are often more aggressively applied where roads traverse areas of steep terrain or erodible soils, especially in geographical areas that receive high levels of precipitation.

Permanent deactivation is done with the expectation that the road will no longer be used by the person required to deactivate it. The road will receive no further inspections or maintenance. Permanent deactivation of mainline and primary branch roads is seldom carried out since these higher-order roads provide access for future harvesting and other needs. Permanent deactivation is thus usually limited to in-block roads and cutblock access roads, and to roads that provide duplicate access to areas.

Permanent deactivation will normally result in the elimination of motor vehicle access along road segments where unstable road fill is pulled back and where stream culverts and bridges are removed. However, for roads that cross flat or gentle terrain with no stream crossings, little or no work may be necessary to permanently deactivate the roads. In this case, motor vehicle access may be both possible and acceptable, unless there is a requirement in a higher-level plan to eliminate such access.

A permanently deactivated road is simply Crown land and no permit is required for use of the land base for motor vehicle access. The road location must be shown on a forest development plan, but can be removed from the plan in the second year following the district manager's acceptance. Retaining the old road location (with expired tenure) on atlas maps does no harm, as the former route may be useful in some emergency.

## Water management techniques

Water management is one of two activities in road deactivation. In lieu of maintenance, water control elements that require routine maintenance can frequently be "fail-safed" by adding self-maintaining elements that, if properly installed, are less prone to failure. This is simply a back-up should the other element fail due to irregular or a complete absence of maintenance. Restoring or maintaining surface drainage patterns and control of subsurface drainage, consistent with natural drainage patterns, can be achieved by one or more of the following water management techniques.

### *Cross-ditch across an intact road*

The purpose of a cross-ditch is to intercept road surface and ditchline water and convey it across the road onto stable, non-erodible slopes below the road (Figure 22).

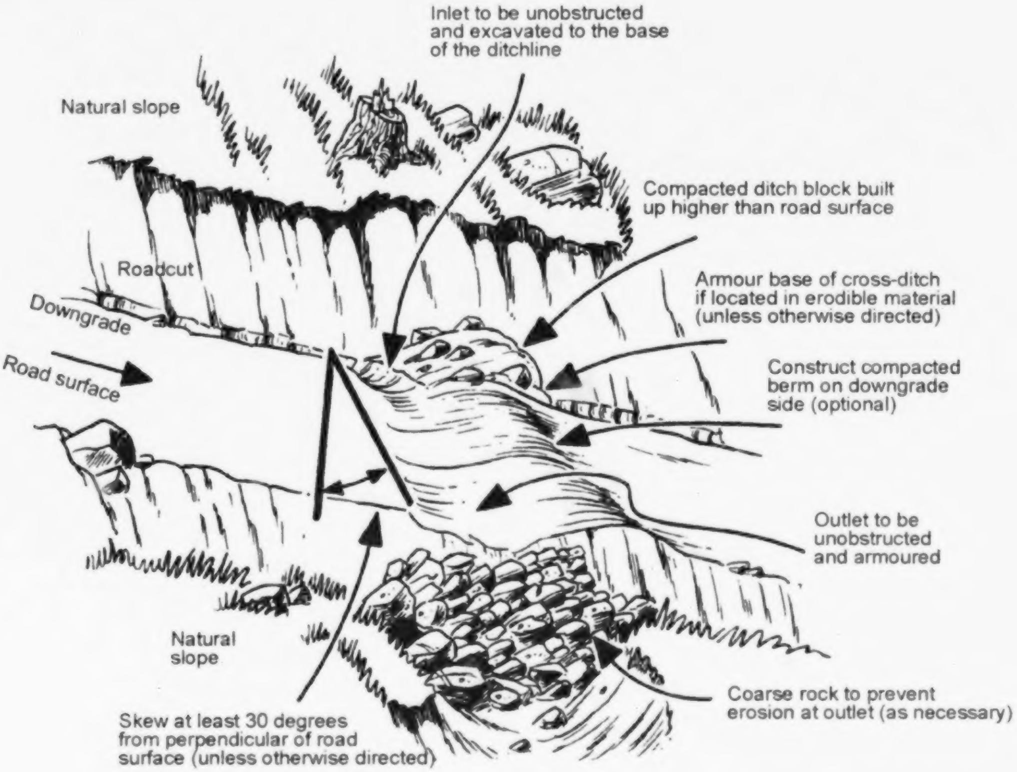

Inlet to be unobstructed and excavated to the base of the ditchline
Natural slope
Compacted ditch block built up higher than road surface
Roadcut
Downgrade
Armour base of cross-ditch if located in erodible material (unless otherwise directed)
Road surface
Construct compacted berm on downgrade side (optional)
Outlet to be unobstructed and armoured
Natural slope
Coarse rock to prevent erosion at outlet (as necessary)
Skew at least 30 degrees from perpendicular of road surface (unless otherwise directed)

**Figure 22.** Cross-ditch installation across an intact road.

A well-compacted ditch block should be installed immediately downgrade of the cross-ditch inlet. For permanent or semi-permanent deactivation, the ditch block is usually higher than the road surface. The ditch block should be non-erodible, relatively impermeable, and large enough to divert all expected flows into the cross-ditch. Where ditchwater converges at low points in the road, no ditch block or berm is required, as the cross-ditch should be constructed as a broad gentle swale.

- Armour the base of the cross-ditch if erosion or rutting of the subgrade is expected to cause a problem for future road access. Armour the outlet of the cross-ditch, unless noted in the prescriptions. Size and placement of the armour will depend on the anticipated flows and downstream consequences.
- Use angular rock large enough to protect exposed soil, but small enough so as not to divert or obstruct flows. Where coarse rock is unavailable, other methods of protecting the outlet area may include revegetation, erosion control mats, sandbags, soil bioengineering, or appropriately sized and placed woody debris.

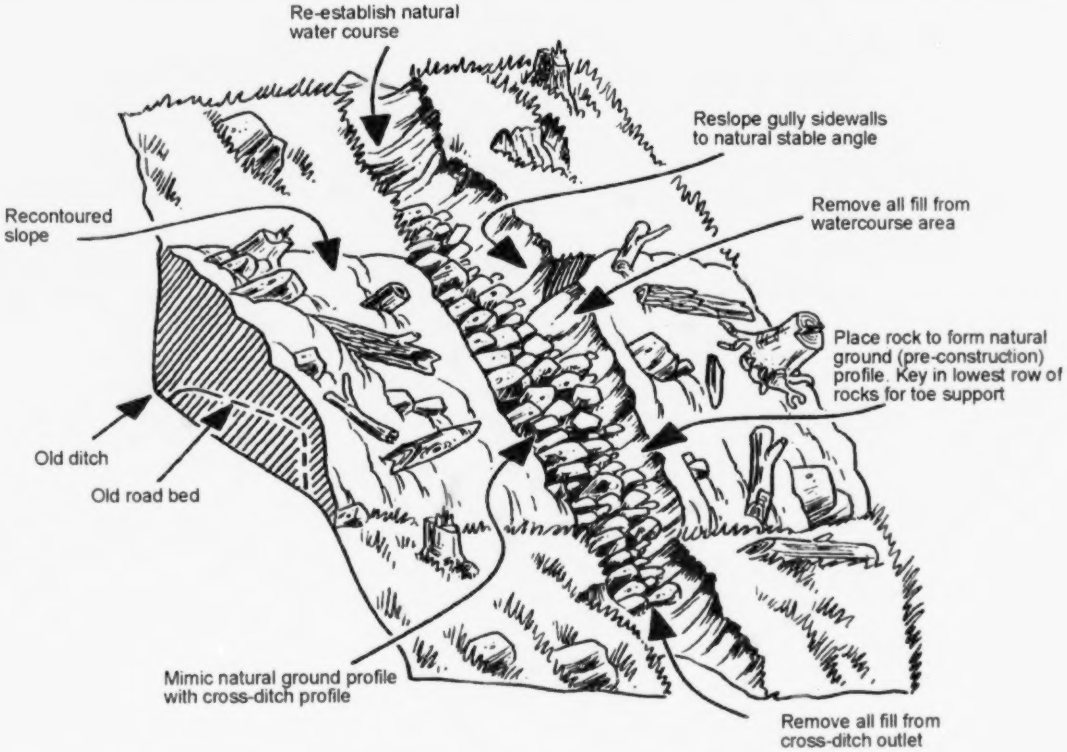

Re-establish natural water course
Reslope gully sidewalls to natural stable angle
Recontoured slope
Remove all fill from watercourse area
Place rock to form natural ground (pre-construction) profile. Key in lowest row of rocks for toe support
Old ditch
Old road bed
Mimic natural ground profile with cross-ditch profile
Remove all fill from cross-ditch outlet

**Figure 23.** Cross-ditch installation across full road pullback.

### *Cross-ditch in full pullback*

The purpose of a cross-ditch located within segments of full road fill pullback is to restore the natural hillslope drainage paths to pre-construction (historic) locations along the hillslope (Figure 23).

Armouring the base of cross-ditches constructed within fill slope pullback zones may not be needed in cases of very low flows, or where the flows are not hydraulically connected to larger streams in the watershed (fish habitat or water supply areas), or if no sedimentation is expected.

- Where cross-ditches in pullback are located at stream crossings, restore the width and natural gradient of the stream and armour the stream banks (sides of the cross-ditch) and the base of the channel.
- Flatten the sides of the cross-ditch as necessary to prevent slumping of fill into the stream.
- Consider also excavating a stepped channel in non-erodible materials to reduce the flow energy if erodible materials are present downslope.

For sites with no rock where lack of armour is a concern, the potential for erosion can be reduced by widening the base of the cross-ditch or stream channel, flattening the sideslopes to a gentle angle, creating wide flares at the outlet, and ensuring that the outlet grades evenly into the natural ground with no step.

### Waterbars

The purpose of a waterbar is to intercept surface water on the road and convey it across the road onto stable slopes below the road. Waterbars can also be used to reduce the flow energy along the grade. Reverse waterbars direct flow off the road into the drainage ditch (Figure 24).

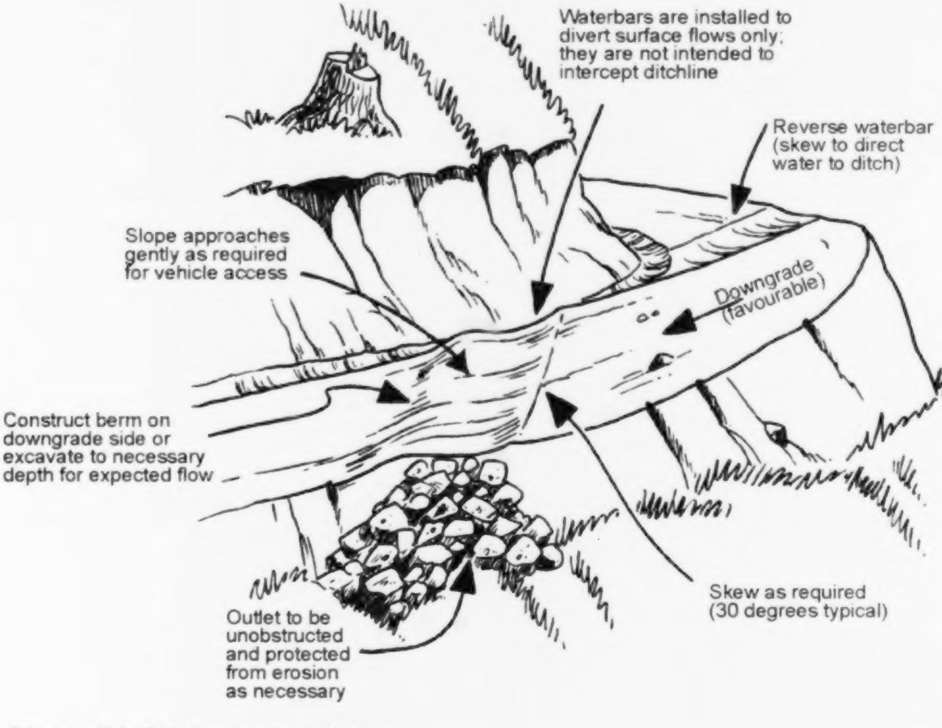

Waterbars are installed to divert surface flows only; they are not intended to intercept ditchline
Reverse waterbar (skew to direct water to ditch)
Slope approaches gently as required for vehicle access
Downgrade (favourable)
Construct berm on downgrade side or excavate to necessary depth for expected flow
Skew as required (30 degrees typical)
Outlet to be unobstructed and protected from erosion as necessary

**Figure 24.** Waterbar installation.

### *Stream culvert removal*

Stream culverts should be pulled and the channel reconstructed where culvert maintenance is impractical or impossible. The objective is to remove an existing metal or plastic pipe, or log culvert, creating the least amount of sedimentation possible and leaving a cross-ditch. This should be done by re-establishing the natural width and gradient of the stream, as well as armouring the stream banks (sides of the cross-ditch) and the base of the channel. The size, depth, and shape of the re-established stream crossing depend on the hillslope and creek/gully contours and expected flows. Figures 25 and 26 show techniques that can be used to remove a pipe or log culvert where running water is present in the channel, and the stream is hydraulically connected to fish habitat or community water supplies.

- At challenging sites, explore the range of practical options with experienced staff or fisheries agencies, to reduce the potential sedimentation to acceptable levels.

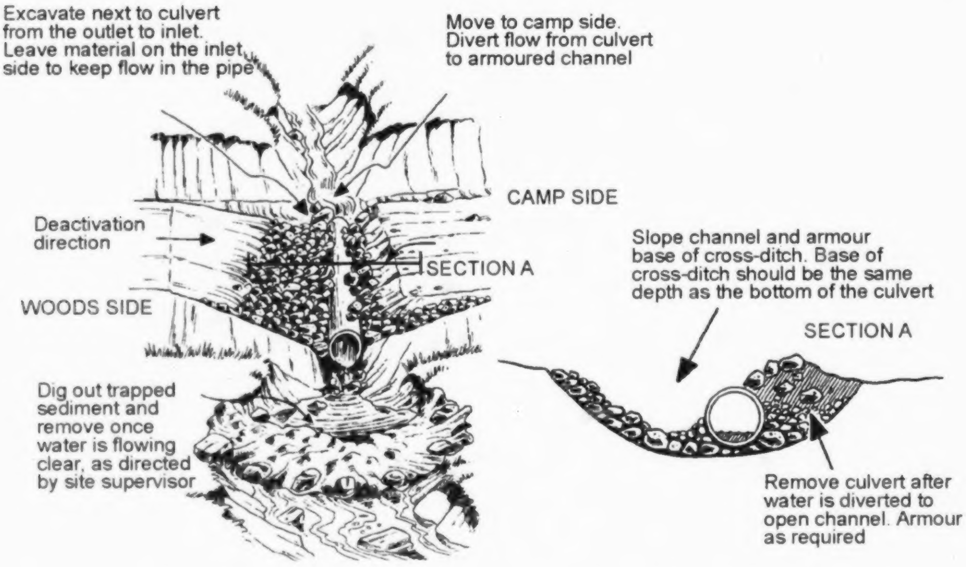

Excavate next to culvert from the outlet to inlet. Leave material on the inlet side to keep flow in the pipe
Move to camp side. Divert flow from culvert to armoured channel
CAMP SIDE
Deactivation direction
SECTION A
WOODS SIDE
Dig out trapped sediment and remove once water is flowing clear, as directed by site supervisor
Slope channel and armour base of cross-ditch. Base of cross-ditch should be the same depth as the bottom of the culvert
SECTION A
Remove culvert after water is diverted to open channel. Armour as required

**Figure 25.** Metal or plastic pipe stream culvert removal (non-fish stream).

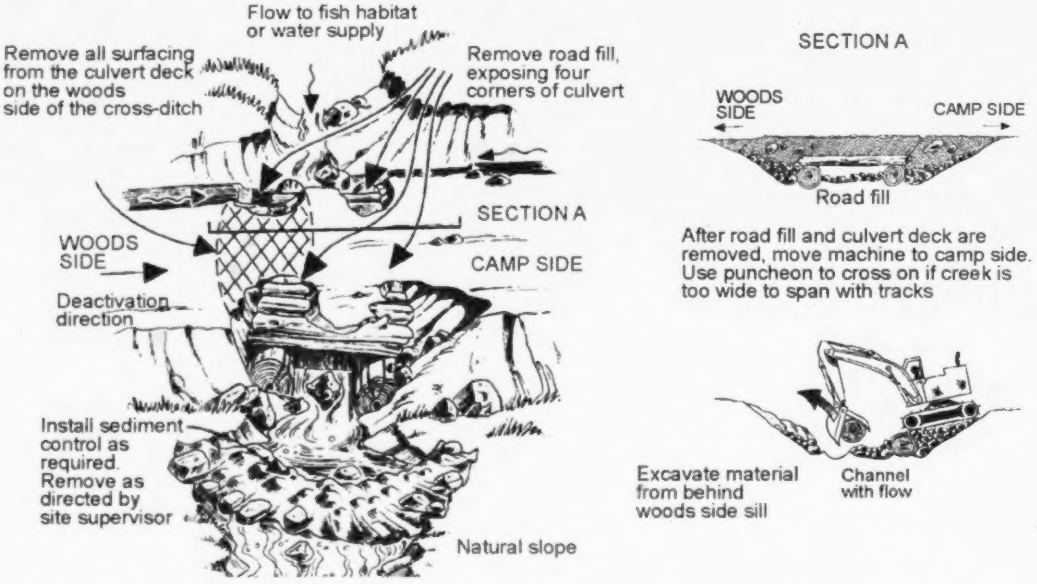

Flow to fish habitat or water supply
Remove all surfacing from the culvert deck on the woods side of the cross-ditch
Remove road fill, exposing four corners of culvert
SECTION A
WOODS SIDE
CAMP SIDE
Deactivation direction
Install sediment control as required. Remove as directed by site supervisor
Natural slope
SECTION A
WOODS SIDE
CAMP SIDE
Road fill
After road fill and culvert deck are removed, move machine to camp side. Use puncheon to cross on if creek is too wide to span with tracks
Excavate material from behind woods side sill
Channel with flow

**Figure 26.** Log stream culvert removal (non-fish stream).

### *Trench drains*

A trench drain is a cross-ditch that has been filled in with coarse rock and built up as the road fill is pulled back against the cut (Figure 27). The purpose of a trench drain is to pass both surface and seepage flow across road fill pullback. Trench drains, which are only prescribed in areas of full (heavy) pullback, are particularly useful where all the space on the road bench must be used for placement of road fill pullback.

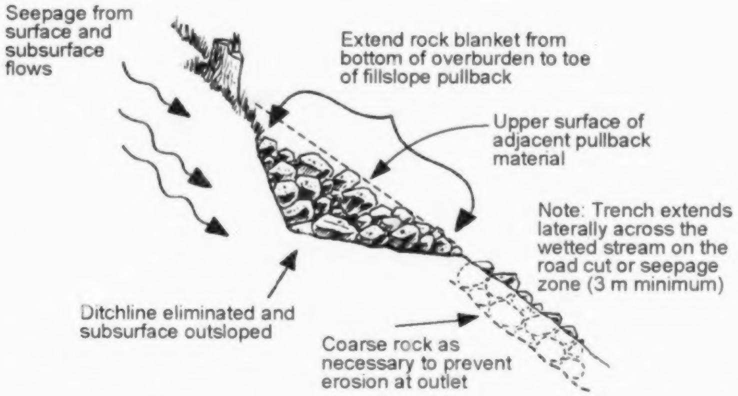

Seepage from surface and subsurface flows
Extend rock blanket from bottom of overburden to toe of fillslope pullback
Upper surface of adjacent pullback material
Note: Trench extends laterally across the wetted stream on the road cut or seepage zone (3 m minimum)
Ditchline eliminated and subsurface outsloped
Coarse rock as necessary to prevent erosion at outlet

**Figure 27.** Trench drain.

The installation procedure is as follows. A ditch is dug across the road from the outlet to inlet, exposing native ground along the full length. The ditch should then be infilled with rock as it is excavated. A geosynthetic filter fabric (non-woven cloth) may help to keep soil from clogging the drain.

To carry the same flow (volume), trench drains are wider than a cross-ditch, but can disperse the water over a broader hillslope area.

### *Blanket drains*

The purpose of a blanket drain is to disperse point seepage or subsurface flow under the road fill pullback. It disperses rather than concentrates the flow at a specific hillslope location. Blanket drains are not intended to convey surface flows or replace open cross-ditches in areas of substantial flow.

A blanket drain has a wider "footprint" in plan than a trench drain (it commonly extends a greater lateral distance along the road) to provide increased flow capacity (Figure 28).

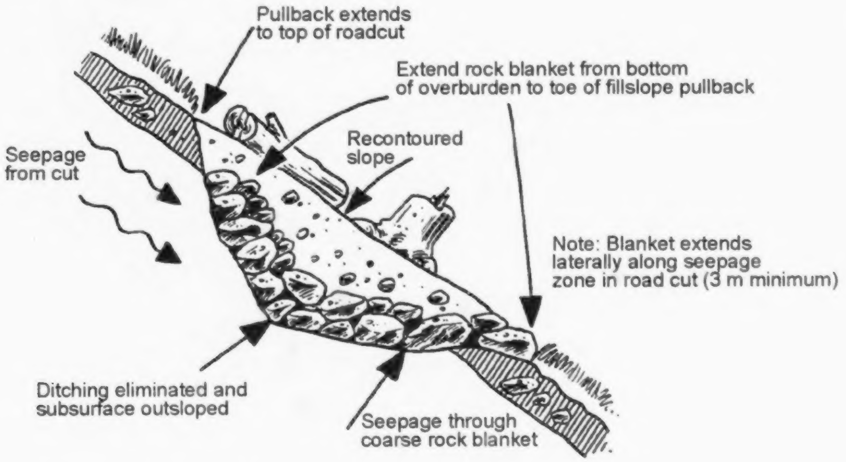

Pullback extends to top of roadcut
Extend rock blanket from bottom of overburden to toe of fillslope pullback
Recontoured slope
Seepage from cut
Note: Blanket extends laterally along seepage zone in road cut (3 m minimum)
Ditching eliminated and subsurface outsloped
Seepage through coarse rock blanket

**Figure 28.** Blanket drain.

## *French drains*

The purpose of a French drain is to divert flow along the base of a cut slope, and to discharge it into a stable location, such as a creek or gully. French drains can be used where road fill pullback or bank sloughing may block the ditch and cause water management problems. They can also provide some degree of water management if the road cannot be decompacted to below ditchline depth. The rock-filled French drain extends down the ditchline until it intersects, and is hydraulically connected with, a cross-ditch or gully.

French drains are normally used in conjunction with road fill pullback, but are sometimes used on active roads with road cut instabilities (Figure 29).

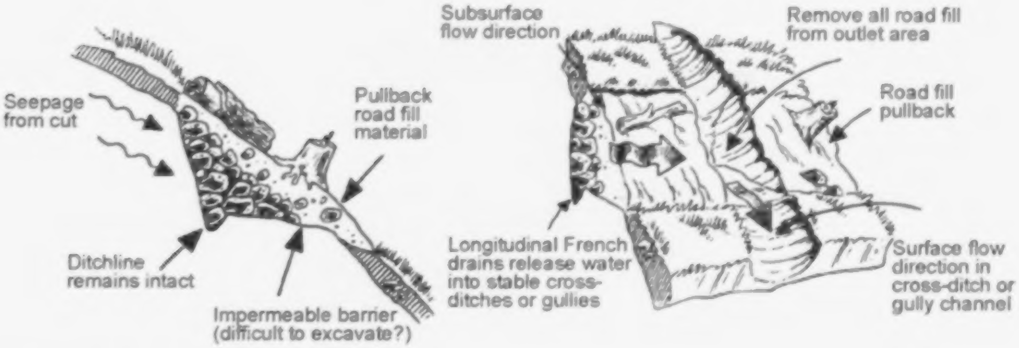

Seepage from cut
Pullback road fill material
Ditchline remains intact
Impermeable barrier (difficult to excavate?)
Subsurface flow direction
Remove all road fill from outlet area
Road fill pullback
Longitudinal French drains release water into stable cross-ditches or gullies
Surface flow direction in cross-ditch or gully channel

**Figure 29.** French drain.

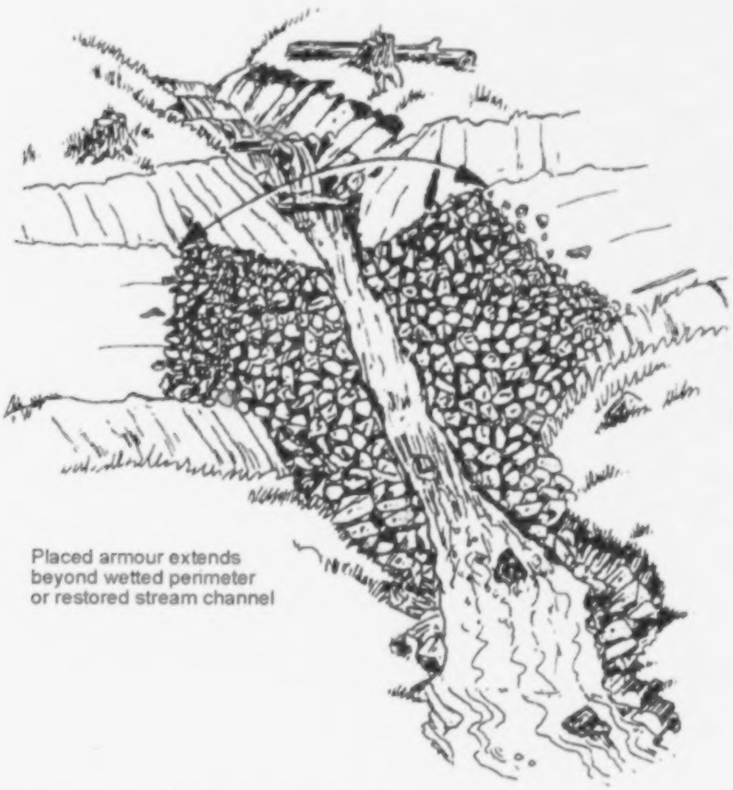
## *Fords and armoured swales*

Fords and armoured swales provide erosion-resistant and storm-proof wet crossings for motor vehicles. A ford is used to cross a stream, whereas an armoured swale is constructed where a cross-ditch would normally be used.

### Fords

A ford is a dip in a road constructed to cross a perennial or ephemeral stream. It is usually designed and built as a permanent feature during original road construction, or during semi-permanent or permanent road deactivation (Figure 30). Fords are restricted to non-fish streams unless otherwise approved by the fisheries agencies. For deactivation, the running surface of the ford is often protected using rock armour where seasonal or ephemeral flows are expected, and is carefully graded to allow continued motor vehicle access.

Where flows are expected continuously during the time the road is in use, consider constructing a modified ford using low-flow culverts. Further future deactivation of fords is not normally required if they are well constructed. In cases where sediment and small woody debris is transported along the stream and could in-fill the voids in the large rock, a visual inspection of the ford may be necessary from time to time.



Placed armour extends
beyond wetted perimeter
or restored stream channel

**Figure 30.** Example of a ford installed on a non–fish-bearing stream.

## Armoured swales

An armoured swale is a dip in the road grade installed to convey road surface runoff, ditchwater, or cutbank seepage across a road where short-term vehicle access is required (Figure 31). It may also be used where it is critical to minimize sedimentation during short-term works such as road deactivation.

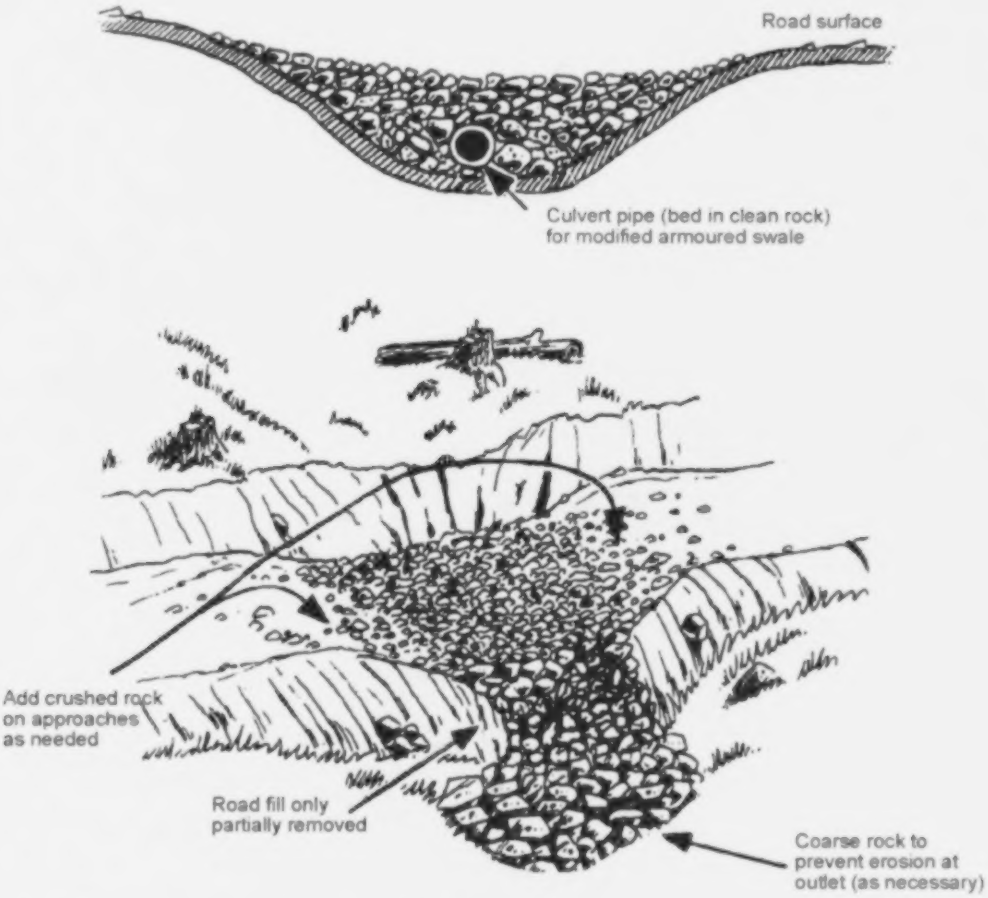
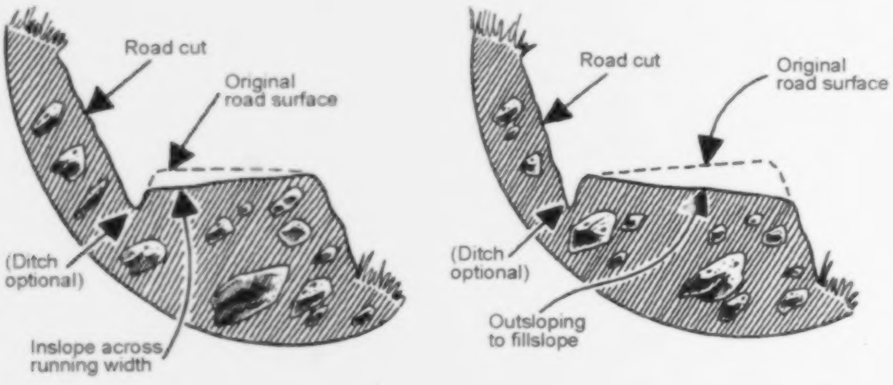

Road surface
Culvert pipe (bed in clean rock) for modified armoured swale
Add crushed rock on approaches as needed
Road fill only partially removed
Coarse rock to prevent erosion at outlet (as necessary)

**Figure 31.** Example of an armoured swale.

### *Insloping/outsloping road surface*

The purpose of insloping or outsloping the road surface is to control water without using ditches or cross-ditches. Insloping directs the water into the road cut, while outsloping directs the water across the road to the fill slope (or road shoulder) (Figure 32). This technique works to disperse water where the road grade is no steeper than about 6%. If used on steeper road grades, recognize that most of the water will tend to run down the road grade rather than flow into the ditch for insloped roads, or off the shoulder for outsloped roads.

This technique may be effective on roads where there is very little vehicle traffic. But where roads receive regular traffic, the insloping or outsloping will disappear with grading and development of wheel ruts. Outsloping also can be a driving hazard and is not recommended for roads travelled by heavy vehicles.


Road cut
Original road surface
(Ditch optional)
Inslope across running width
Road cut
Original road surface
(Ditch optional)
Outsloping to fillslope

**INSLOPING** **OUTSLOPING**

**Figure 32.** Insloping and outsloping the road surface.

### *Windrow or roadside spoil pile pullback*

The purpose of windrow or roadside spoil pile pullback is to restore natural hillslope drainage paths where road maintenance activities have left a continuous soil berm on the outer edge (or inner edge) of the road. Larger berms may also be pulled back to reduce the weight on the outside edge of the road, or to satisfy silvicultural reasons (Figure 33).

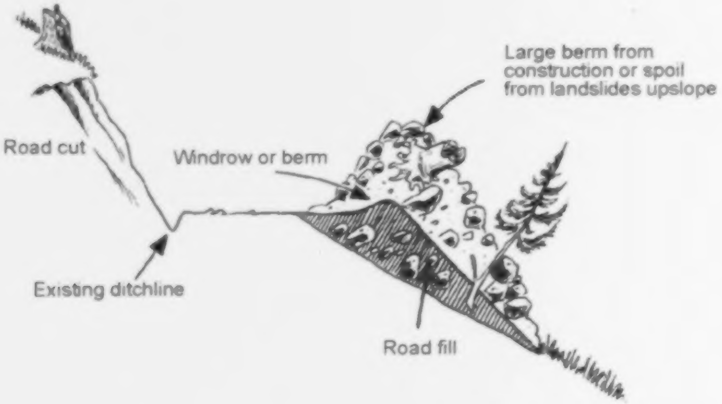

Large berm from construction or spoil from landslides upslope
Road cut
Windrow or berm
Existing ditchline
Road fill

**Figure 33.** Grader windrow and spoil pile berm (site conditions before fill pullback).

## Road fill pullback

In addition to water management, stable cut and fill slopes are required to prevent road-related landslides. Without regular maintenance, particularly on steep slopes, the stability of road cuts and fills can deteriorate. Usually, road fill pullback will be carried out only where required along selected segments of road, while water management techniques may be carried out at specific locations within or adjacent to the pullback areas. Where there is potential for unstable road cut or fill slopes to develop during periods of inattention, full road fill pullback or partial road fill pullback (where motor vehicle access may still be required) is commonly carried out. This removes marginally stable sidecast fill that has a high risk of failure, and effectively adds a weighting berm to the toe of the road cut.

### *Full road fill pullback*

The purpose of full road fill pullback is to retrieve all potentially unstable sidecast material and place it tight against the road cut, thereby reducing the landslide hazard to the greatest extent possible. Usually no access or only limited access for foot or ATV traffic is possible after full road fill pullback (Figure 34).

Decompaction may also be necessary. This involves breaking up road fill materials to a depth equal to, or greater than, the depth of the ditch, and removing this material to outslope the surface before pullback material is placed overtop (Figure 34). This may be desirable to promote water flow across the road under the pullback material, to provide for the greater downslope reach of the excavator during pullback, and to allow the operator to determine the width of the natural bench for machine positioning.

If it is not feasible or desirable to decompact the road fill, then drainage collected from the filled-in road ditch can be discharged in a controlled manner by subdrains or open cross-ditches. Where very long and deep road fills are present, benching and/or ramping may be necessary to retrieve all the sidecast fill material.

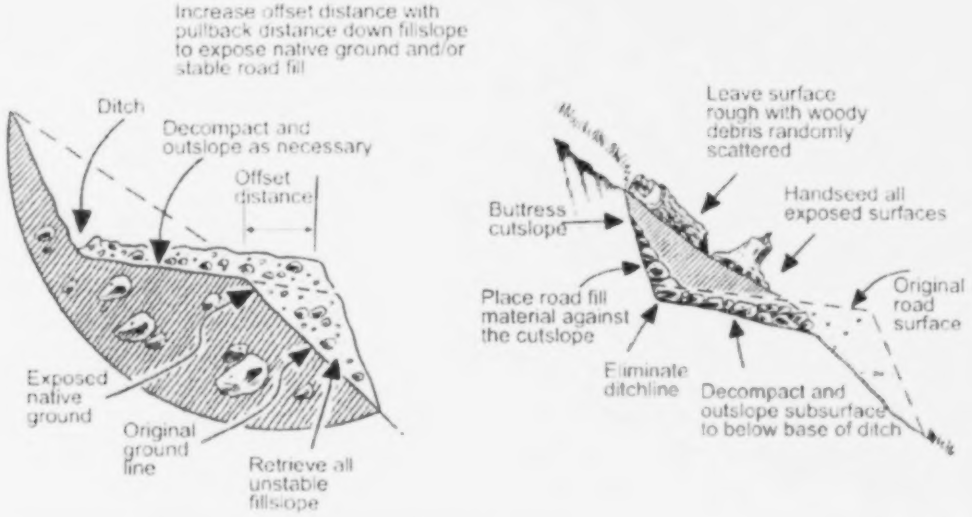

Increase offset distance with pullback distance down fillslope to expose native ground and/or stable road fill
Ditch
Decompact and outslope as necessary
Offset distance
Exposed native ground
Original ground line
Retrieve all unstable fillslope
Leave surface rough with woody debris randomly scattered
Handseed all exposed surfaces
Buttress cutslope
Place road fill material against the cutslope
Original road surface
Eliminate ditchline
Decompact and outslope subsurface to below base of ditch

**Figure 34.** Example of full road fill pullback.

### *Partial road fill pullback*

The purpose of partial road fill pullback is to reduce the likelihood of a landslide to a tolerable level along the road when full road fill pullback is not needed for immediate stability. Partial road fill pullback retrieves the unstable portion of the road fill and leaves the stable portion intact, but it may not reduce the road fill landslide hazard to the fullest extent possible. This technique may be appropriate to maintain motor vehicle access if the road is open to traffic or if road access is needed in the future. Full road fill pullback may be required at some future date to provide long-term stability of the road prism.

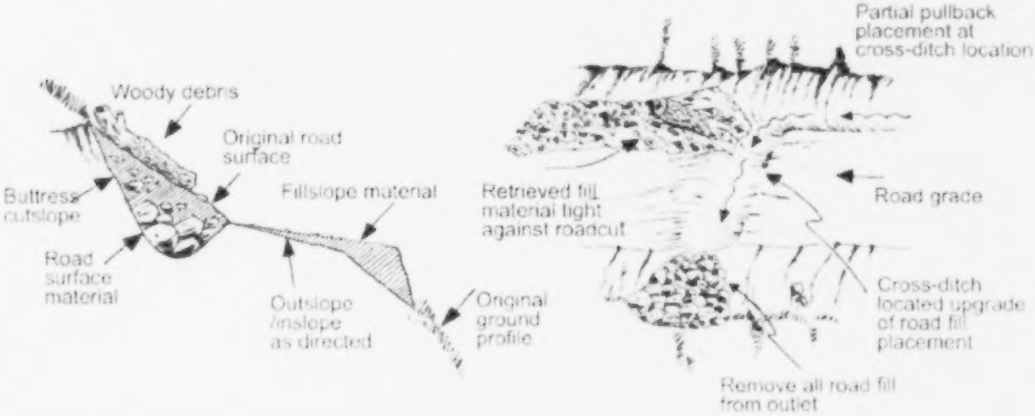

Woody debris
Original road surface
Buttress cutslope
Fillslope material
Road surface material
Outslope /inslope as directed
Original ground profile
Partial pullback placement at cross-ditch location
Retrieved fill material tight against roadcut
Road grade
Cross-ditch located upgrade of road fill placement
Remove all road fill from outlet

**Figure 35.** Partial road fill pullback.

### Endhauling road fill pullback

Endhauling is the removal of excess road fill off-site by truck, and placing it in an approved waste area. Endhauling from unstable hillslopes helps restore the hillslope contour and profile, reducing the potential for future road fill–related landslides.

### Gully restoration

Gully restoration involves pulling back all the fill material out of a gully channel. It is carried out during full road fill pullback to decrease the landslide hazard along the road approaches on the side walls of the gully. The size, depth, and shape of the pullback should mimic the natural ground profiles and contours of the gully system above and below the road. Armouring the gully channel and endhauling is often required. Similar techniques can also be used for entrenched creeks. Refer to the *Gully Assessment Procedure Guidebook* for detailed technical information on the deactivation of road crossings of gully systems.

## Typical applications of deactivation techniques

### Temporary deactivation activities

To meet specific site conditions, temporary deactivation work involves implementation of water management techniques to reduce landslide hazard and to control soil erosion and sediment transport, such as:

- removing or breaching any windrows on the outer edge of the road surface
- repairing or removing bridges as necessary
- constructing waterbars, cross-ditches, or other "fail-safe" or back-up drainage systems along the road, or insloping or outsloping the road as appropriate.

Partially pulling back road fill along road segments at high-risk sites may be necessary.

### Semi-permanent deactivation activities

To protect resources at risk, semi-permanent deactivation work is site specific and may include some of the following techniques:

- removing all or some stream culverts and restoring channel and bank stability, or backing up culverts with cross-ditches as necessary
- replacing all or some cross-drain culverts with cross-ditches or backing them up with cross-ditches or other drainage systems as necessary
- installing cross-ditches or waterbars where there are:
  - steep grades
  - heavy ground water seepages

  - switchbacks or road junctions
  - ditches prone to plugging
  - places where ponding may occur
  - other potential drainage problem areas
- protecting road users during the period of deactivation by removing, repairing, or replacing those bridges that may place users at risk
- removing or breaching windrows on the road surface
- outsloping or insloping the road surface or constructing waterbars as appropriate
- carrying out measures to remove organic material (stumps, roots, embedded logs, topsoil) that may reasonably be expected to fail and de-stabilize the road fill
- pulling back potentially unstable sidecast fill.

### *Permanent deactivation activities*

Permanent deactivation is different than semi-permanent deactivation in the following ways:

- Bridge and log culvert superstructures must be removed. The bridge or log substructures must also be removed if a failure of the substructure could be expected to adversely affect downstream values.
- Stream culverts will usually be removed to ensure there is no potential adverse impact on the stream. Where there is a low risk of damage to fish passage or water quality, pipe culverts at stream crossings may be left in place, *provided that the district manager approves the permanent deactivation prescription.*
- Cross-drain culverts should be removed and replaced with cross-ditches to re-establish drainage patterns, especially on steep road grades and side hills. If the likelihood of failure is minimal or the consequences of a failure are low, consideration may be given to leaving the cross-drain culvert intact, provided it is backed up with a cross-ditch or armoured swale as necessary.

## Methodology to develop deactivation prescriptions

### *Definition and purpose of a prescription*

A deactivation prescription is a written document that clearly communicates the objectives and the works to be performed.

#### District manager approval of prescriptions

For temporary deactivation, prescription approval is not required, unless the proponent is notified in writing that the proponent must prepare a deactivation prescription and obtain the district manager's approval of it. For all semi-permanent and permanent deactivation, the proponent must prepare a prescription and, unless exempted from doing so under the Forest Road Regulation, obtain the district manager's approval.

**Note:** The exemption is from obtaining the district manager's approval of the prescription, not from preparing a prescription.

A deactivation prescription will:

- report the level of required deactivation, the objectives of the planned deactivation work, the vehicle access requirements, and the techniques to be performed by station
- report special requirements (e.g., worker safety issues and other important requirements explained later)
- where required, provide relevant detailed information to the district manager for approval.

It is good practice to retain the following:

- original field notes
- final deactivation maps, tabular summary, and letter or report, as applicable
- any relevant correspondence.

Prescription development involves three sequential phases: office review, field assessment, and preparing maps, tabular summary, letter or report. These phases are discussed briefly below.

### Office review

Prior to field work, conduct an office-based review of existing information and local knowledge to help identify the potential resources at risk, terrain stability concerns (especially below the road corridor), sediment and landslide hazards, and consequences at and adjacent to the road.

### Field assessment

Carry out a field assessment and prescribe deactivation techniques at specific locations. This task typically involves the following activities: traversing the road corridor and identifying potential stability and drainage hazards, evaluating the risk to resources, and marking prescription activities in the field. It is important to consider the risk to downslope and downstream resources when developing prescriptions, not only the landslide hazard associated with the road.

The following should be evaluated before a deactivation technique or combination of techniques are chosen:

- the proposed level of deactivation and type of vehicle access following deactivation, as approved in the forest development plan. Where actual field conditions result in a changed level of vehicle usage, then an amendment to the forest development plan is required
- the stability of the road cuts and fills, condition of culverts and bridges, performance of the existing road drainage system, existing sediment sources, and potential for further deterioration of road structures and prism
- the stability of the terrain below (and in some cases above) the road corridor
- any existing access problems that may prevent or impede excavator access to the end of the road to start the deactivation work (locations where large landslides have destroyed the road grade in gully areas, large cut slope landslides, existing deactivation work, etc.).

An example field data form for foot-based field assessment is shown in Appendix 8.

Refer to Chapter 3, "Road Construction," for examples of surface soil erosion and sediment control techniques that should be considered for road deactivation. Road works shutdown indicators and procedures are also provided in Chapter 3 and should also be considered when carrying out road deactivation works.

### *Preparing maps, tabular summary, letter or report*

A deactivation map, or work plan, to scale is mandatory plus one or more of the following:

- a tabular summary of prescribed techniques, by station
- a letter or report.

These requirements are more fully discussed below. Examples showing the linkage between various site and project conditions, and the minimum content of a road deactivation prescription, are provided in Appendix 9.

#### Content of deactivation map (work plan)

The minimum requirement is a map at 1:5000 scale or other suitable scale. The following should be considered for illustration on the map, as deemed appropriate to effectively communicate the design requirements of the work to equipment operators and supervisory personnel:

- level of deactivation (temporary, semi-permanent, permanent) and intended duration (if not permanent)

- vehicle usage (4-wheel drive, ATV, no access)
- topographic information
- additional relevant planimetric information (e.g., streams, bodies of water, legal boundaries, landslides, utilities, highways)
- additional supporting information such as stream classifications, and timing windows and measures for work in and around stream crossings (where necessary)
- sites of potential concern for worker safety
- requirements for field reviews by a qualified registered professional
- special requirements for work carried out within a community watershed
- location of all prescribed deactivation techniques (road chainage and prescription symbol)
- legend for prescription symbols
- date of the assessment
- name of the assessor
- scale bar and north arrow.

**Note:** Some items above may be provided in the tabular summary rather than on the 1:5000 scale map if this would more clearly depict the work.

## Content of tabular summary

Appendix 8 shows a suggested format for a tabular summary (spreadsheet) of prescribed actions to accompany and complement the above map. A tabular summary is usually required where more detail must be given to communicate the requirements of the project to forestry operations personnel, or where the risk of damage to adjacent resources is moderate or high, or where rechaining may be necessary to re-establish the field markings.

As a minimum, the tabular summary should contain the measured chainages along the road, the associated recommended actions, and more detailed comments about site conditions, worker safety issues, key reference points, rationale for road fill pullback, depth and width of cross-ditches, and other such practical information. The tabular summary can also be used as a tool to help estimate the costs of road deactivation works.

## Content of letter or report

A report should accompany and complement deactivation maps and tabular summaries where there is a high risk to the environment, if the project is large or complex, or if roads traverse areas of moderate to high likelihood of landslides. For small projects, a brief letter rather than a report may be sufficient. Reports may require sign-off by a qualified registered professional, licensee representative, or the district manager. A report or letter should cover the following topics, as relevant:

- geographical location information (watershed name and number, cutting permit)
- background information
- description of deactivation objectives
- prescription methodology
- road reactivation considerations (road reconstruction, wet crossings, safety issues)
- site-level information
- results and recommendations
- site plans and illustrations.

## Involvement of professionals in road deactivation

### *Linkage between TSFA and deactivation prescriptions*

A qualified registered professional must prepare a deactivation prescription where the road crosses areas having a moderate or high likelihood of landslides, as determined by a terrain stability field assessment (TSFA).

#### Pre-Code terrain issues

On an existing road where no TSFA exists, one will have to be completed as required by the Forest Road Regulation. A qualified registered professional can conduct the TSFA as a separate forest management activity prior to the development of a deactivation prescription for the road. However, it is more common for the TSFA to be carried out concurrently with a deactivation field assessment and prescription where the registered professional is qualified to conduct both assessments. A pre-Code TSFA may not be deemed acceptable. Appendix 10 provides a qualitative risk assessment procedure that may be appropriate to determine risk to adjacent resources.

#### Post-Code terrain issues

In the following situations, a new Code TSFA may be required:

- **Example 1:** A road TSFA was completed according to Code requirements and before a road was constructed. It showed a low likelihood of landslides, but segments of the road now show visual indicators of slope instability and risk to adjacent resources
- **Example 2:** No road TSFA was prepared before a road was constructed, because it was not required by the Code. The road corridor now shows signs of instability and risk to adjacent resources.

Care should be taken in verifying indicators of slope instability in the following situations:

- Tension cracks or minor slumps in the road surface do not necessarily signal unstable terrain, but rather a failing road fill. Partial pullback of the road fill may be appropriate to stabilize the road prism and protect users of the road and adjacent resources.
- If the slope instability indicators occur outside the road prism (e.g., a small slide), or the instability within the road prism has the potential to affect adjacent resources (e.g., debris from a potential fill slope failure could reach a fish stream), the area should be considered unstable.

### *Professional field reviews – quality assurance*

The rationale for a professional field review should be stated in the TSFA or the deactivation prescription, and should describe any specific concerns and the potential consequences of not carrying out professional field reviews. As well, it should identify the requirements of the person appropriate to complete the professional field reviews.

Note that the cost to carry out road fill pullback a second time to repair deficiencies can be much higher than the cost of the original pullback work. Thus, thorough field reviews are prudent for full road fill pullback above high-value resources (such as highways and residential development).

### *Professional field reviews – unanticipated subsurface conditions*

Unanticipated subsurface conditions can be encountered during deactivation works. In such an event, and if potential adverse impacts to adjacent resources are identified, the forest tenure holder should consult a qualified registered professional for a professional field review before continuing with the project.

### *Modification of prescriptions*

To address unforeseen site conditions, the proponent is often forced to modify the prescription. If the proponent has reasonable grounds to believe that the changes to the prescription would not adversely affect forest resources or future access objectives, the proponent may make the required changes without further approval. If there is a potential for adverse impact, however, the changes to the prescription must be approved by the district manager. At the start of the project, it is often useful to establish a protocol for the types of changes that can be made on site.

For prescriptions that must be prepared by a qualified registered professional, that person or another similarly qualified registered professional, in addition to the district manager, must also approve all changes to the prescription.

## Revegetation requirements for deactivated roads

To control surface soil erosion and sediment transport, the Code requires that a proponent who deactivates a road must revegetate all exposed soils that will support vegetation. This should be done by applying seed in the first growing season. For information on application of grass seed, see Chapter 3, "Road Construction."

Vegetation must be established, to the satisfaction of the district manager, by the end of the second growing season. The district manager may vary this time period or the process for revegetation if satisfied that the change will adequately manage and conserve the forest resources. The district manager may also consider natural revegetation appropriate if it can be suitably established within two growing periods. Revegetation is considered to be successful when there is uniform coverage on the ground. Spotty or clumpy patches of vegetation are not considered adequate.

The district manager should consider the following factors in assessing the adequacy of revegetation efforts:

- the mixture of the grass seed used
- the time and rate at which the seed was applied
- the appropriateness of the fertilizer and mulch used
- the number of attempts made to establish the vegetation.

### *Scarification*

In addition to grass seeding requirements, it may be necessary to scarify the road surface or to re-use local topsoils or other measures to grow trees for soil erosion control purposes in those areas that are not part of the net area to be reforested, but where trees can be reasonably expected to grow.

**Note:** Scarification is for revegetation purposes, whereas decompaction is for water control during fill pullback activities.

Scarification (also known as "silvicultural fluffing") is done to enhance revegetation. It involves breaking up the road surface to a minimum depth equal to about twice the length of the teeth on an excavator bucket (about 400 mm, or 16 inches). Scarification is more important for those road surfaces where the materials are well graded, or where high traffic volumes have compacted the road surface. A silviculture forester should be consulted to determine the necessity of scarification relative to planned tree species and site index parameters along the road.

Field observations (prescription indicators) that may lead to a scarification prescription are as follows:

- road surface is compacted
- road fill is stable; no pullback needed
- planting of conifers is better than existing revegetation at the site
- local experience indicates that conifers do poorly on compacted road surfaces
- road is stable and no further access is needed.

### *Woody species establishment*

In addition to Code requirements for grass seeding of all deactivated roads where necessary, carry out additional revegetative measures for permanently deactivated roads, including the localized re-use of topsoil to grow trees for soil erosion purposes.

For permanently deactivated roads, consider planting pioneering species such as alder, willow, and, in some cases, lodgepole pine and Douglas-fir on areas of full road fill pullback or on areas that have been scarified. These species are important early colonizers of disturbed sites, and prepare the site for later successional forest species such as spruce, cedar, and hemlock.

The use of topsoil and tree planting to achieve revegetation (outside the net area to be reforested) on a permanently deactivated road should simply be for the purpose of controlling soil erosion. There is no requirement to reforest all permanently deactivated roads, even when it is feasible to reforest. The choice of reforestation rests with the person required to deactivate the road. A qualified forester or biologist should review the selection of tree species for planting on any permanently deactivated roads.

### *Soil bioengineering*

Where revegetation is difficult, discussions with revegetation specialists may be helpful. Applying soil bioengineering systems for water management on steep slopes, and for riparian restoration, should be considered with the following objectives:

- drain excess moisture that may be creating slope instability (e.g., live pole drains, live silt fences, live bank protection, live gully breaks, and live staking)
- reduce slope angles relative to the growth of vegetation and prevent ravelling of fill slopes (e.g., wattle fences, modified brush layers, brush layers in a cut)
- control erosion along watercourses (e.g., live gravel bar staking, and live shade).

### *Control of noxious weeds*

Knapweed and other noxious weeds are found along many old logging roads and should be considered during deactivation assessment. Consulting a range agrologist may be warranted to minimize the likelihood of spreading these problem weeds through machine travel or seed disturbance, if scheduling deactivation work outside the seed maturity time is not possible.

## Deactivation hazard warning signs

Before deactivation activities begin, install hazard warning signs at appropriate locations to warn potential users of the road (either open or closed to traffic) of the hazards that can be expected on the road on a continuous basis or at a particular road location. Where an entire drainage or system of roads has been deactivated, the signs can be posted at the earliest location to forewarn of the upcoming hazards.

Sign maintenance can be a serious problem, especially during the hunting season. These signs may be destroyed as fast as they are erected. If this is an ongoing risk to road users, the person conducting an inspection should be prepared to replace them.

## Post-deactivation inspections and maintenance

Refer to Chapter 5, "Road and Structure Inspection and Maintenance," for information on the inspection and repair requirements for temporary and semi-permanent deactivation.

## Acceptance of permanent deactivation

The ministry should inspect the road before accepting it as being permanently deactivated. The district manager may provide for a time period to elapse to test the ability of the deactivation work to withstand a normal cycle of weathering. Upon final inspection, the district manager may notify the person responsible for deactivating the road in writing that the road has been permanently deactivated.

## Suggestions for further reading

British Columbia Ministry of Forests and B.C. Ministry of Environment, Lands and Parks. 2001. *Best Management Practices Handbook: Hillslope Restoration in British Columbia*. Victoria, B.C.

British Columbia Ministry of Forests. 2001. *Gully Assessment Procedure Guidebook*. Victoria, B.C.

____________. 2002. *Fish-stream Crossing Guidebook*. Victoria, B.C.

Bulmer, Chuck. (editor). 2000. *Forest Road Deactivation Practices in the Pacific Northwest*. B.C. Ministry of Forests, Forest Science Program. Victoria, B.C.

Forestry Continuing Studies Network (FCSN). 1997. *Advanced Road Deactivation Course Manual*. Victoria, B.C.

Forest Engineering Research Institute of Canada (FERIC). 2001. *Compendium of Watershed Restoration Activities: Techniques and Trials in Western Canada*. Vancouver, B.C.

# Appendix 1. Field identification of soils

## Describing soils

Soil classification systems are based mainly on particle size, and these usually fall into three main groups: coarse-grained soils, fine-grained soils, and organic soils.

### *Coarse-grained soils*

These contain particle sizes that are large enough to be visible to the naked eye. They include gravels and sands and are generally referred to as cohesionless, or non-cohesive, soils. Strictly defined, coarse-grained soils have more than 50% of the dry weight larger than particle size 0.060 mm (Table A1.1).

### *Fine-grained soils*

These contain particle sizes that are not visible to the naked eye. They are identified primarily on the basis of their behaviour in a number of simple indicator tests. They include silts and clays, the latter of which are generally referred to as cohesive soils. The term "cohesive" indicates stickiness in soils. Strictly defined, fine-grained soils are soils having more than 50% of the dry weight smaller than particle size 0.060 mm (Table A1.1).

### *Organic soils*

These soils have a high (80%) natural organic content.

These three main groups are further divided into a series of subgroups, each determined by particle size divisions within the major groups.

In addition to particle size identification, soil classification also includes a description of such properties as "consistency" of a cohesive soil and "density" of a non-cohesive soil in its natural undisturbed state in the field. For example, consistency is a term that is used to describe the degree of firmness of cohesive soil and is indicated by such descriptive terms as soft, firm, or hard. In practice, the term is used only in reference to the condition of the cohesive fine-grained soils such as clayey silts, silty clays, and clays (i.e., those that are markedly affected by changes in moisture content). The term is not usually applied to coarse-grained soils such as sands and gravels or to non-cohesive silts.

As a cohesive soil changes consistency, its engineering properties change also. The strength of a soil varies considerably with consistency. A clay at a low moisture content and in a hard condition is obviously stronger than the same clay at a high moisture content and in a soft condition. Thus, classifying a clay by particle size alone is insufficient for engineering purposes. The classification should also take the consistency into account.

Classifying soils in the field is usually difficult to do precisely. One person may describe a soil as soft, another may say it is very soft. Similarly, whether a particular soil is a fine sand or very fine sand cannot usually be determined through field identification alone. To eliminate the subjectivity from these decisions, a series of laboratory classification tests has been developed. Nevertheless, field identification remains important. Experienced soils personnel can estimate most of these properties by making careful field observations and examining small samples of the soil. Even personnel without considerable soils experience can, using the field identification guidelines summarized here, generally describe the properties successfully.

## Soil composition

Composition includes the grain size and range of particle sizes, shape, and plasticity. The plasticity of a soil refers to the range of moisture content that determines its plastic condition. The coarse-grained soils (sand and gravels) are described primarily on the basis of grain size, and the fine-grained soils (silts and clays) primarily on the basis of plasticity.

A guide to field identification by the grain size of coarse-grained soils is summarized in Table A1.1.

**Table A1.1.** Grain size identification (consistent with the *Canadian Foundation Engineering Manual*).

| Soil Groups | Soil Type Name | | Size Limits of Particles | Familiar Size Example |
|---|---|---|---|---|
| Coarse-grained soils | Boulders | | 200 mm (8 in) or larger | Larger than bowling ball |
| | Cobbles | | 60 mm (2½ in) – 200 mm (8 in) | Grapefruit |
| | Gravels | Coarse gravel | 20 – 60 mm | Orange or lemon |
| | | Medium gravel | 6.0 – 20.0 mm | Grape or pea |
| | | Fine gravel | 2.0 – 6.0 mm | Rock salt |
| | Sands | Coarse sand | 0.60 – 2.0 mm | Sugar |
| | | Medium sand | 0.20 – 0.60 mm | Table salt |
| | | Fine sand | 0.06 – 0.20 mm | Icing sugar |
| Fine-grained soils | Silts | | 0.02 – 0.06 mm | Cannot be discerned with naked eye at a distance of 200 mm (8 in) |
| | Clays | | Less than 0.02 mm | Use simple field tests to distinguish between silts and clays (e.g., stickiness, dilatancy) |

## Soil consistency

The consistency of a cohesive soil—described as hard or soft—can be estimated from the pressure required to squeeze an undisturbed sample between the fingers. An undisturbed sample is one that is in its natural condition as on or in the ground; it has not been remoulded by any mechanical disturbance, such as bulldozer tracks.

If the soil is brittle (fails suddenly with little movement as it is squeezed), friable (crumbles easily), or sensitive (loses much of its strength when remoulded and then resqueezed), these terms should be included in the description of the soil's consistency.

A guide to estimating consistency in this way is summarized in Table A1.2.

**Table A1.2.** Consistency field test for cohesive soils.

| Field Test | Term |
|---|---|
| Easily penetrated several centimetres by fist. | Very soft |
| Easily penetrated several centimetres by thumb. | Soft |
| Penetrated several centimetres by thumb with moderate effort. | Firm |
| Readily indented by thumb but penetrated only with great effort. | Stiff |
| Readily indented by thumbnail. | Very stiff |
| Indented with difficulty by thumbnail. | Hard |

## Soil density

The density of a non-cohesive soil may be estimated in the field by the ease with which a reinforcing rod penetrates the soil. It is quoted in relative terms, such as loose or dense. A guide to estimating soil density is summarized in Table A1.3.

**Table A1.3.** Soil density field test for non-cohesive soils.

| Field Test | Term |
|---|---|
| Easily excavated with spade. | Very loose |
| Easily penetrated with 13 mm (0.5 in) reinforcing rod pushed by hand or, alternatively, shows some resistance to spade or penetration with hard bar. | Loose |
| Easily penetrated with 13 mm (0.5 in) reinforcing rod driven with a 2.25 kg (5 lb) hammer or, alternatively, shows considerable resistance to spade or penetration with hard bar. | Compact |
| Penetrated 0.3 m (1 ft) with 13 mm (0.5 in) reinforcing rod driven with 2.25 kg (5 lb) hammer or, alternatively, shows no penetration with hard bar or requires pick for excavation. | Dense |
| Penetrated only a few centimetres with 13 mm (0.5 in) reinforcing rod driven with 2.25 kg (5 lb) hammer or, alternatively, shows high resistance to pick. | Very dense |

## Soil compressibility

A soil's potential for compressibility is not easy to determine by visual examination alone. This is usually done by laboratory tests. However, if it is suspected that the soil will settle considerably under load, this should be reported.

There is a general relationship between consistency (as defined for cohesive soils) or soil density (as defined for non-cohesive soils) and compressibility. For example, the soft and loose soils are likely to compress considerably under loads.

## Reporting soil description

In forming a description, the predominant particle size is what is used to describe the soil type. The relative content of other particle sizes modifies the description (e.g., sand GRAVEL with some silt).

A predominantly coarse-grained soil is termed either a gravel or a sand, depending on which component appears to be the more abundant. The less abundant component and the fines are used as modifiers; the least important component is stated first. For example, a soil with 30% fines (silt), 45% gravel, and 25% sand would be best described as sandy, silt GRAVEL. The terms in Table A1.4 are used to indicate various proportions by weight within the respective grain-size fractions.

**Table A1.4.** Soils description terms.

| Descriptive Term | Example by Weight | Proportion |
|---|---|---|
| NOUN | GRAVEL, SAND, SILT, CLAY | >50% |
| "and" | and gravel, and silt, etc. | >35% |
| ADJECTIVE | gravelly, sandy, silty, clayey, etc. | 20–35% |
| "Some" | Some sand, some silt, etc. | 10–20% |
| "Trace" | Trace sand, trace silt, etc. | 1–10% |

For example:

- A "silty CLAY, trace of fine sand" would be >50% clay, 20–35% silt, and 0–10% sand.
- A "sandy GRAVEL with some cobbles" would be >50% gravel with 20–35% sand sizes and 10–20% cobbles.

# Appendix 2. Vertical (parabolic) curves

The relative flatness, or "K" value of a vertical (parabolic) curve, is the horizontal length over which there is a 1% change of grade. The minimum length of a vertical curve is solved as the K value times "A," the algebraic difference between the entry and exit grades (LVC = K*A). When the length of the vertical curve (LVC) is equal to or exceeds the stopping sight distance (SSD), the K value is given by the expression:

Crest

$$K = \frac{SSD^2}{200(H_1^{0.5} + H_2^{0.5})^2}$$

$H_1$ height of driver's eye: 1.05 m
$H_2$ height of object: one-lane road - 1.30 m (vehicle)
two-lane road - 0.15 m (object)

Sag

$$K = \frac{SSD^2}{200\left(H_3 + SSD\ \mathrm{Tan}1°\right)}$$

$H_3$ height of headlight: 0.6 m

**Table A2.1.** Minimum K values, where LVC > SSD.

| | | Crest | | Crest | Sag |
|---|---|---|---|---|---|
| **Design speed (km/h)** | **Minimum SSD[a] (m)** | **One-lane** | **Minimum SSD (m)** | **Two-lane** | **One-lane** |
| 20 | 40 | 1.7 | 20 | 1.0 | 2.1 |
| 30 | 65 | 4.5 | 35 | 3.1 | 5.1 |
| 40 | 95 | 9.6 | 50 | 6.3 | 8.5 |
| 50 | 135 | 19.4 | 70 | 12.3 | 13.4 |
| 60 | 175 | 32.7 | 90 | 20.3 | 18.7 |
| 70 | 220 | 51.6 | 110 | 30.3 | 24.0 |
| 80 | 270 | 77.8 | 135 | 45.7 | 30.8 |

[a] Values of minimum stopping sight distance apply to one-lane, two-way roads. For two-lane and one-lane, one-way roads, multiply the values of minimum SSD by a factor of 0.5.

When the LVC is less than the minimum SSD, the K values are solved by the expression:

Crest

$$K = \frac{2SSD}{A} - \frac{200(H_1^{0.5} + H_2^{0.5})^2}{A^2}$$

Sag

$$K = \frac{2SSD}{A} - \frac{200(H_3 + SSD \text{ Tan } 1°)}{A^2}$$

**Table A2.2.** Minimum K values, where LVC < SSD.

**Crest curve: One-lane, two-way road**

| Design speed (km/h) | A | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | | | | | | | | | | | 0.2 | 0.6 | 0.9 | 1.2 | 1.3 | 1.5 | 1.6 | 1.6 |
| 30 | | | | | | | 1.6 | 2.9 | 3.6 | 4.1 | 4.3 | | | | | | | |
| 40 | | | | 0.5 | 5.6 | 8.0 | 9.1 | 9.5 | | | | | | | | | | |
| 50 | | | 8.9 | 16.5 | 19.0 | | | | | | | | | | | | | |
| 60 | | 12.5 | 28.9 | 32.5 | | | | | | | | | | | | | | |
| 70 | | 42.5 | 51.4 | | | | | | | | | | | | | | | |
| 80 | 35.7 | 75.9 | | | | | | | | | | | | | | | | |

**Crest curve: Two-lane road**

| | A | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Design speed (km/h) | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 20 | | | | | | | | | | 0.3 | 0.6 | 0.7 | 0.8 | 0.9 | 0.9 |
| 30 | | | | | 0.6 | 1.9 | 2.5 | 2.9 | 3.0 | | | | | | |
| 40 | | | 0.1 | 4.1 | 5.6 | 6.1 | | | | | | | | | |
| 50 | | 2.4 | 10.1 | 12.1 | | | | | | | | | | | |
| 60 | | 15.7 | 20.1 | | | | | | | | | | | | |
| 70 | 10.3 | 29.0 | | | | | | | | | | | | | |
| 80 | 35.3 | | | | | | | | | | | | | | |

**Sag curve: One- and two-lane road**

| | A | | | | | | |
|---|---|---|---|---|---|---|---|
| Design speed (km/h) | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 20 | | | | 0.4 | 1.4 | 1.8 | 2.0 |
| 30 | | | 2.4 | 4.3 | 4.9 | | |
| 40 | | 0.6 | 6.6 | 8.2 | | | |
| 50 | | 6.2 | 12.2 | | | | |
| 60 | | 11.8 | 17.9 | | | | |
| 70 | | 17.3 | 23.5 | | | | |
| 80 | | 24.3 | 30.5 | | | | |

**Table A2.3.** Vertical curve elements (crest curve, single-lane road).

| A[a] | 20 km/h | 30 km/h | 40 km/h | 50 km/h | 60 km/h | 70 km/h | 80 km/h |
|---|---|---|---|---|---|---|---|
| **Crest curve: single-lane road** | | | | | | | |
| 2 | | | | | | | 71 |
| 3 | | | | | 38 | 128 | 228 |
| 4 | | | | 36 | 116 | 206 | 311 |
| 5 | | | 3 | 83 | 163 | 258 | 388 |
| 6 | | | 34 | 114 | 196 | 310 | 467 |
| 7 | | | 68 | 136 | 229 | 361 | 544 |
| 8 | | 13 | 73 | 156 | 261 | 413 | 622 |
| 9 | | 26 | 86 | 175 | 294 | 465 | 700 |
| 10 | | 36 | 96 | 194 | 327 | 516 | 778 |
| 11 | | 45 | 106 | 214 | 359 | 568 | 856 |
| 12 | 2 | 52 | 116 | 233 | 392 | 620 | 933 |
| 13 | 8 | 58 | 125 | 263 | 425 | 671 | 1011 |
| 14 | 13 | 63 | 136 | 272 | 457 | 723 | 1089 |
| 15 | 18 | 68 | 144 | 292 | 490 | 775 | 1167 |
| 16 | 21 | 72 | 154 | 311 | 523 | 826 | 1244 |
| 17 | 25 | 77 | 164 | 331 | 555 | 878 | 1322 |
| 18 | 28 | 81 | 173 | 350 | 588 | 929 | 1400 |
| 19 | 31 | 86 | 183 | 369 | 621 | 981 | 1478 |
| 20 | 33 | 90 | 193 | 389 | 653 | 1033 | 1555 |
| 21 | 36 | 95 | 202 | 408 | 686 | 1084 | 1633 |
| 22 | 37 | 99 | 212 | 428 | 719 | 1136 | 1711 |
| 23 | 39 | 104 | 221 | 447 | 751 | 1188 | 1789 |
| 24 | 41 | 108 | 231 | 467 | 784 | 1239 | 1867 |
| Minimum SSD (m) | 40 | 65 | 95 | 135 | 175 | 220 | 270 |

[a] Algebraic difference between the entry and exit grades (%).

**Table A2.4.** Vertical curve elements (crest curve, double-lane road).

| A[a] | 20 km/h | 30 km/h | 40 km/h | 50 km/h | 60 km/h | 70 km/h | 80 km/h |
|---|---|---|---|---|---|---|---|
| **Crest curve: double-lane road** | | | | | | | |
| 2 | | | | | | 21 | 71 |
| 3 | | | | 7 | 47 | 87 | 137 |
| 4 | | | | 40 | 80 | 121 | 183 |
| 5 | | | 20 | 60 | 102 | 152 | 229 |
| 6 | | 4 | 34 | 74 | 122 | 182 | 274 |
| 7 | | 13 | 43 | 86 | 142 | 212 | 320 |
| 8 | | 20 | 50 | 98 | 163 | 243 | 366 |
| 9 | | 26 | 56 | 111 | 183 | 273 | 411 |
| 10 | | 30 | 63 | 123 | 203 | 303 | 457 |
| 11 | 4 | 34 | 69 | 135 | 223 | 334 | 503 |
| 12 | 7 | 37 | 75 | 147 | 244 | 364 | 548 |
| 13 | 9 | 40 | 82 | 160 | 264 | 394 | 594 |
| 14 | 12 | 43 | 88 | 172 | 284 | 425 | 640 |
| 15 | 13 | 46 | 94 | 184 | 305 | 455 | 686 |
| 16 | 15 | 49 | 100 | 197 | 325 | 486 | 731 |
| 17 | 17 | 52 | 107 | 209 | 345 | 516 | 777 |
| 18 | 18 | 55 | 113 | 221 | 366 | 546 | 823 |
| 19 | 19 | 58 | 119 | 233 | 386 | 577 | 868 |
| 20 | 20 | 61 | 125 | 246 | 406 | 607 | 914 |
| 21 | 21 | 65 | 132 | 258 | 427 | 637 | 960 |
| 22 | 22 | 68 | 138 | 270 | 447 | 668 | 1006 |
| 23 | 23 | 71 | 144 | 283 | 467 | 698 | 1051 |
| 24 | 24 | 74 | 150 | 295 | 488 | 728 | 1097 |
| Minimum SSD (m) | 20 | 35 | 50 | 70 | 90 | 110 | 135 |

[a] Algebraic difference between the entry and exit grades (%).

**Table A2.5.** Vertical curve elements (sag curve).

| A[a] | 20 km/h | 30 km/h | 40 km/h | 50 km/h | 60 km/h | 70 km/h | 80 km/h |
|---|---|---|---|---|---|---|---|
| **Sag curve** | | | | | | | |
| 2 | | | | | | | |
| 3 | | | 2 | 19 | 35 | 52 | 73 |
| 4 | | 9 | 26 | 49 | 71 | 94 | 122 |
| 5 | 2 | 22 | 41 | 67 | 93 | 120 | 154 |
| 6 | 8 | 30 | 51 | 81 | 112 | 144 | 185 |
| 7 | 13 | 35 | 59 | 94 | 131 | 168 | 216 |
| 8 | 16 | 40 | 68 | 108 | 149 | 192 | 247 |
| 9 | 19 | 46 | 76 | 121 | 168 | 216 | 277 |
| 10 | 21 | 51 | 85 | 134 | 187 | 240 | 308 |
| 11 | 23 | 56 | 93 | 148 | 205 | 264 | 339 |
| 12 | 25 | 61 | 102 | 161 | 224 | 288 | 370 |
| 13 | 27 | 66 | 110 | 175 | 243 | 312 | 401 |
| 14 | 30 | 71 | 119 | 188 | 261 | 336 | 432 |
| 15 | 32 | 76 | 127 | 202 | 280 | 360 | 462 |
| 16 | 34 | 81 | 136 | 215 | 298 | 384 | 493 |
| 17 | 36 | 86 | 144 | 229 | 317 | 408 | 524 |
| 18 | 38 | 91 | 153 | 242 | 336 | 432 | 555 |
| 19 | 40 | 96 | 161 | 256 | 354 | 456 | 586 |
| 20 | 42 | 101 | 170 | 269 | 373 | 480 | 616 |
| 21 | 44 | 106 | 178 | 282 | 392 | 504 | 647 |
| 22 | 46 | 111 | 187 | 296 | 410 | 528 | 678 |
| 23 | 48 | 116 | 195 | 309 | 429 | 552 | 709 |
| 24 | 51 | 121 | 204 | 323 | 448 | 576 | 740 |
| Minimum SSD (m) | 20 | 35 | 50 | 70 | 90 | 110 | 135 |

[a] Algebraic difference between the entry and exit grades (%).

# Appendix 3. Plotting data: plan and profile information

Plans/profiles and plotted cross-sections should be completed for the field survey. The plans and profiles should be prepared in 1 km sections on a 1 m plan/profile sheet with a minimum 200 m overlap between drawings. The plan/profile should be drawn to a scale of 1:2000 horizontally and 1:200 vertically.

The example plan/profile drawing in this appendix illustrates the plan and profile information requirements listed below. The drawing is available at the following Ministry of Forests website:
http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/guidetoc.htm

*Plans should include all information pertinent to the project:*

- north arrow with magnetic declination shown
- preliminary line traverse (include turning points, TPs)
- accumulated chainage and TP number at every fifth TP
- overlap between plans of 200 m
- chainage equations
- reference points and benchmarks plotted and labelled
- existing roads complete with road name
- existing structures (bridges, culverts, buildings, fences, etc.)
- existing services and utilities including but not restricted to telephone, power, gas, oil, sewer and water lines, and fences
- percent side slope and direction
- terrain features and direction (rock outcrops, creeks, rivers, swamps, wet areas, riparian zones, etc.)
- timber types, number, diameter, and species or stumps within the clearing widths
- designed L-line complete with curves
- curve information including radius (R), angle of intersection (IC), length of curve (LC), beginning of curve (BC), and end of curve (EC)
- accumulated L-line chainage at beginning and end of curves
- bearing of the L-line tangents shown on the plan to the nearest 30 seconds
- kilometre stations on the L-line
- 100 m of existing road alignment from junction or extension of existing points
- clearing and right-of-way boundaries

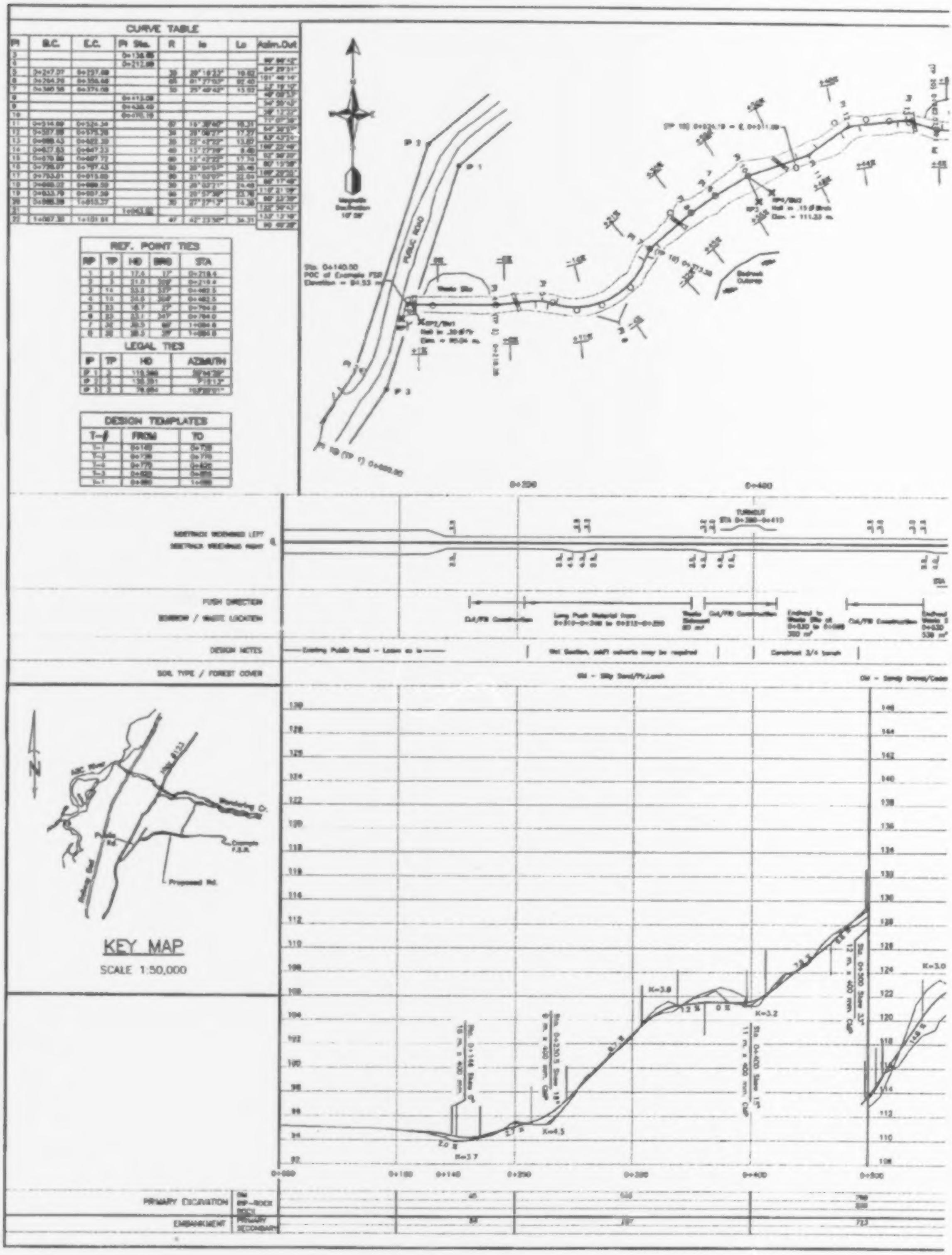
- title block indicating road name, kilometre, date of survey, and scale (horizontal and vertical)
- special notes indicating land district, road width, survey level, and datum of elevation
- all legal boundaries and plan numbers
- all monumentation found and tied within 300 m of the P-line, including a traverse tie table.

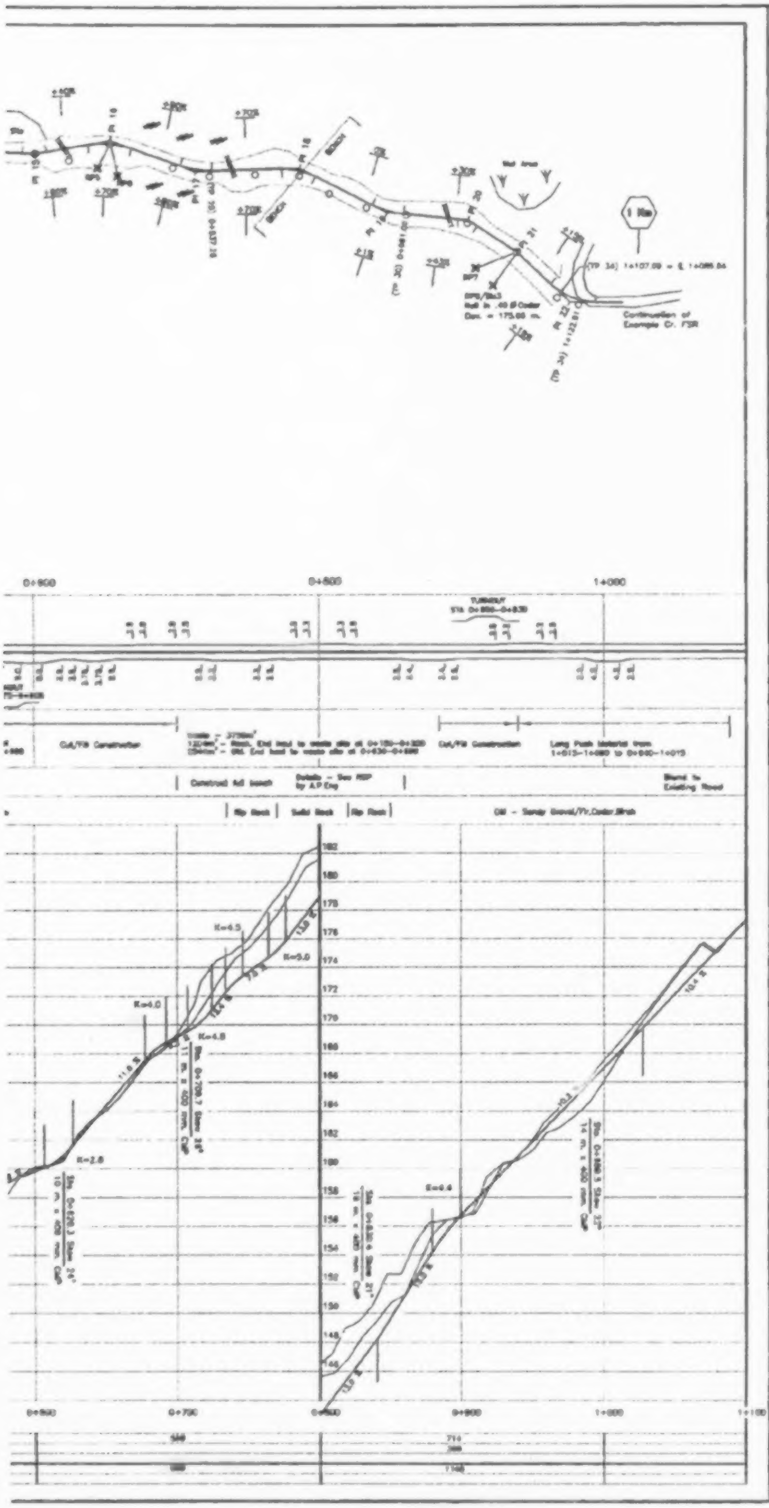
A key map should also be included on the first drawing of the set to a scale of 1:50 000. Note that no curves are required where I is less than or equal to 5°.

*Profiles should include the following information:*

- chainage and elevation equations
- description of soils (at least every 200 m or at soil change)
- terrain features (creeks, rivers, swamps, wet areas, riparian areas, etc.)
- penetration depths at swamps and wet areas to solid ground, if possible
- grade lines completed with percent grades labelled (adverse or negative)
- grade breaks at grade changes of 2% or less
- vertical curves at grade changes greater than 2%
- turnout locations and dimensions
- design notes (extra ditching, lateral ditching, road widenings, etc.)
- culvert locations with recommended diameter, length, and skew
- kilometre stations
- primary excavation and primary embankment volumes summarized in bank cubic metres at 200 m intervals
- secondary embankment (gravel) volumes summarized in bank cubic metres at 200 m intervals
- waste and borrow locations, quantities in bank cubic metres, and quantity movements
- scale: H = 1:2000; V = 1:200
- 100 m of existing road grade and horizontal alignment at junction
- balance points and direction of material movement
- position of cut and fill slope changes

- PWL and HWL, where applicable
- span lengths for bridges
- all control points
- design templates
- K values if used for vertical curves.


CURVE TABLE
REF. POINT TIES
LEGAL TIES
DESIGN TEMPLATES
PUBLIC ROAD
0+200
0+400
PUSH DIRECTION
BORROW / WASTE LOCATION
DESIGN NOTES
SOIL TYPE / FOREST COVER
KEY MAP
SCALE 1:50,000
Proposed Rd.
0+000
0+100
0+140
0+200
0+300
0+400
0+500
PRIMARY EXCAVATION
EMBANKMENT


1 Km
Continuation of Example Cr. FSR
0+600
0+800
1+000
Cut/Fill Construction
Long Push Material from
Blend to Existing Road
Rip Rock
Solid Rock
K=4.5
K=5.0
K=4.0
K=4.8
K=2.8
K=4.4
182
180
178
176
174
172
170
168
166
164
162
160
158
156
154
152
150
148
146
0+600
0+700
0+800
0+900
1+000
1+100

## MOF EXAMPLE F.S.R.
## PLAN/PROFILE
Km. 0 to Km. 1

Province of British Columbia
MINISTRY OF FORESTS

### SCALE

PLAN
1 : 2000

PROFILE
H 1 : 2000
V 1 : 200

### DESIGN SPECIFICATIONS

Stabilized Subgrade Width – 5.0 meters
Ditch Width – 1.25 meters
Design Speed – 30 km/h
Crest Curves ( min. 'K' ) – 3.0
Sag Curves ( min. 'K' ) – 1.5
Survey Level : 3

Turnouts
length: 15 m
width: 2.5 m
tapers: 7.5 m ea.

### TEMPLATES

| TEMPLATE # | MATERIAL | CUT | FILL | EMBANKMENT CORR. FACTOR |
|---|---|---|---|---|
| T-1 | O.M. Dry | 1.00 : 1 | 1.50 : 1 | 1.2 |
| T-2 | O.M. Wet | 1.50 : 1 | 1.50 : 1 | 1.2 |
| T-3 | Rippable | 0.75 : 1 | 1.25 : 1 | 1.0 |
| T-4 | Rock | 0.25 : 1 | 1.25 : 1 | 0.8 |
| T-5 | Gravel |  | 2.00 : 1 | 1.2 |

### PLAN LEGEND

PROPOSED C/L
EXISTING ROAD
CLEARING LIMITS
LEGAL PROPERTY BOUNDARY
PI # POINT OF INTERSECTION (ON PROPOSED C/L)
○ PLINE STATION (TP)
CULVERT LOCATION
CREEK
INTERMITTENT CREEK
× RP REFERENCE POINT
B.M. BENCH MARK
● IP 3 IRON POST FOUND

CHAINAGE REVISION FROM P-LINE TO L-LINE
0+100.0 T.P. 5 = ℄ 0+099.6
Pline Station, Hub No., Lline Station

### PROFILE LEGEND

L-LINE GROUNDLINE
P-LINE GROUNDLINE
L-LINE GRADE

|  | Date |
|---|---|
| Survey: (Engineering surveyor) |  |
| Design: (Geometric road designer) |  |
| Drawing: |  |
| Checked: |  |
| Approved: |  |

| REV | DESCRIPTION | BY | APPR. | DATE |
|---|---|---|---|---|
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

Measures to Maintain Slope Stability, prepared by ______________

and dated __/__/__ were incorporated into this geometric road design.

______________

### VOLUME SUMMARY

| BANK CUBIC METERS |  |  | Kilometer Totals | Project Totals |
|---|---|---|---|---|
| EMBANKMENT | PRIMARY |  | 2,840 | 2,840 |
|  | SECONDARY |  | 430 | 430 |
|  | GRAVEL DEPTH |  | 0.1 m | 0.1 m |
| EXCAVATION | PRIMARY | RIP ROCK | 536 | 536 |
|  |  | ROCK | 0 | 0 |
|  |  | O.M. | 2,860 | 2,860 |
| BORROW |  |  | 0 | 0 |
| WASTE |  |  | 4,710 | 4,710 |
| TOTAL STRIPPING HA. |  |  | 1.502 | 1.502 |

Drawing No. 11250-30/1234
Sheet 1 of 1
REV. B

# Appendix 4. Statement of construction conformance

## Statement of Construction Conformance
## (Construction of Bridges, Major Culverts, and Other Structures)

*TO BE SUBMITTED **AFTER** COMPLETION OF THE PROJECT*

| | | |
|---|---|---|
| **Structure Identification No. / Name** | **Road Name:** | **Location** |

| | | |
|---|---|---|
| **Forest District & Forest Region** | **Crossing Name**(as applicable) | **Project No.** (as applicable) |

| | |
|---|---|
| **Structure Description:**<br>☐ Bridge ☐ Major Culvert ☐ Other | **List of Approved Design Drawings:**<br>Drawing and Revision No. / Name of Designer/Date: |

I am a Professional Engineer or Professional Forester, and I have undertaken professional responsibility for all field reviews required with respect to this structure. I have taken steps as regulated under the Provincial Statute for my profession, and as required by good practice and in accordance with the division of professional responsibility specified in the Forest Practices Code (FPC) of British Columbia, in order to sign and seal this Statement of Construction Conformance as required by FPC, Forest Road Regulation Part 3, Section 13.

In my professional opinion:

- the as-built structure is in general conformance with the design drawings, specifications and all applicable supporting documents, including all design amendments, which supported the acceptance of the project by the appropriate authority;
- sufficient field reviews have been carried out at appropriate times during the construction work; and
- significant revisions to the drawings, specifications and supporting documents prepared for this project, including all design amendments, have been documented and marked on a set of design/construction drawings marked "as-built" and where necessary described in supporting documents.

As used herein, "field reviews" means field reviews of the work at the project site [and/or at the fabrication location(s), where applicable] considered necessary by, and at the discretion of, the registered professional engineer or professional forester (as appropriate) to confirm that the as-built structure is in general conformance with the approved design/construction drawings, specifications and other supporting documents prepared for this project.

| | | |
|---|---|---|
| Signature of Professional Engineer/Professional Forester | | *(please affix professional seal here)* |
| Name of Professional Engineer/Professional Forester *(please print)* | DATE SIGNED<br>YYYY MM DD | |
| EMPLOYER'S NAME AND ADDRESS *(please print)* | | |
| PHONE NO. | FAX NO. | E-MAIL ADDRESS |

November 2001

# Appendix 5. Tables to establish clearing width

## *Clearing width*

The **clearing width** is shown in Figure 2 of Chapter 1, "Road Layout and Design." Since clearing width calculations are straightforward, but very tedious, Tables A5.1 to A5.7 and accompanying Tables A and B have been developed for your convenience.

These tables provide **slope distances** (not the horizontal distances) for establishing suitable offset distances from road centreline to facilitate easy field marking of the upper and lower clearing width boundaries. Note that the offset slope distances in the tables depend on several factors:

- unstabilized subgrade width
- side slope angle of the natural ground surface
- angles of the fill and cut slopes.

Using the tables in this appendix, the **clearing width** is the sum of the width determined from the tables and any additional width to account for special circumstances (see "Additions to clearing width" in this appendix). The clearing width established from these tables may be expressed as:

**Clearing width** = offset distance on cut side of centreline (from tables) +
offset distance on fill side of centreline (from tables) +
additional width (if necessary)

For a specific subgrade width, these tables assume:

- no horizontal or vertical adjustments at the road centreline
- 0.3 m overburden thickness
- 3 m clearing allowance above the top of the cut slope to standing timber
- selection of the appropriate cut and fill slope angles
- a ditch depth of 0.5 m
- sidecast road construction with little or no longitudinal movement of material
- a minimum 3 m distance from the road shoulder to the lower side clearing width boundary.
- where there is road fill, the toe of the fill slope demarcates the lower clearing width boundary. Therefore, to establish the clearing width when using these tables, include additional width allowances as required (e.g., additional width will be required for debris and slash disposal on the lower side of the road below the toe of the fill slope).

Where the offset slope distance from the road centreline to the upper or lower clearing width boundaries exceeds 50 m, consider using alternative construction methods, such as retaining walls, to reduce the clearing width requirements.

## Determining clearing width from tables in this appendix

The following procedure is recommended:

1. Select the appropriate unstabilized subgrade width table (the tables have been developed for unstabilized subgrade widths of 4, 5, 6, 7, 8, 9, and 10 m). This is done:
   - after adjusting the road subgrade width to compensate for cuts or fills (see "Adjustments to road subgrade width to compensate for cuts and fills at road centreline")
   - after adjusting the road subgrade width to compensate for road surfacing materials (see "Additions to clearing width" in this appendix).
2. Choose the appropriate natural side slope angle in the selected subgrade width table.
3. Based on the expected soil type to be encountered during road construction, choose the appropriate cut and fill slope angles for application in the tables. Details about selecting cut and fill slope angles for road design are given in Appendix 1, "Field identification of soils."
4. To establish the upper clearing width boundary, read the offset slope distance from the appropriate cut slope angle column—the offset distance given in the cut slope angle column is a slope distance between the road centreline and the upper clearing width boundary.
5. Use a two-step procedure to establish the lower clearing width boundary. Firstly, read the offset slope distance from the appropriate fill slope angle column—the offset distance given in the fill slope angle column is a slope distance between the road centreline and the toe of any fill slope. Secondly, include any additional width allowances such as those for slash disposal on the lower side of the road below the toe of the fill, sight distance, etc., as explained in "Additions to clearing width" in this appendix.

### *Adjustments to road subgrade width to compensate for cuts and fills at road centreline*

Use of an adjusted road subgrade width in these tables for short sections of anticipated cuts or fills at the road centreline should be limited to the obvious locations in the field, such as where cuts are required through small ridges or fills across linear slope depressions less than 3 m deep. For longer sections of road through areas with deep gullies or high ridges, a geometric road design should be completed and the clearing width determined from these drawings.

1. To compensate for a cut at the centreline, adjust the road subgrade width as follows: Add 1 m to the subgrade width for every 0.3 m cut increment at centreline to determine the offset slope distance on the cut side of centreline. Subtract 1 m from the subgrade width for every 0.3 m cut increment at centreline to determine the offset slope distance on the fill side of centreline.

   For example, consider a 0.6 m deep cut at centreline on a 6 m wide unstabilized subgrade (assume no surfacing material is applied to the subgrade). Assume a natural side slope angle of 35% above and below the road centreline, and fill and cut slope angles of 1½H : 1V and 1H : 1V, respectively. In this case, adjust the unstabilized subgrade width by 2 m as follows:

   - Choose the appropriate cut slope angle column from Table A5.5 (8 m wide unstabilized subgrade) to determine the offset slope distance on the cut side of centreline. The offset slope distance from this table is 12 m.
   - Choose the appropriate fill slope angle column from Table A5.1 (4 m wide unstabilized subgrade) to determine the offset slope distance on the fill side of centreline. The offset slope distance from this table is 5 m.

   In this cut example, the clearing width (magnitude) is unchanged, but is shifted upslope with respect to the road centreline.

   If, because of shallow side slopes, the 0.6 m cut resulted in a through-cut instead of a fill slope, use the appropriate cut slope angle column from Table A5.1 (4 m wide unstabilized subgrade) to obtain the required offset slope distance from centreline to the lower clearing width boundary.

2. To adjust for fills at the centreline, reverse the above procedure. For example, to allow for a 0.6 m fill at centreline on a 6 m wide road, adjust the unstabilized subgrade width by 2 m as follows:

   - Choose the appropriate cut slope angle column from Table A5.1 (4 m wide unstabilized subgrade) to determine the offset slope distance on the cut side of centreline.
   - Choose the appropriate fill slope angle column from Table A5.5 (8 m wide unstabilized subgrade) to determine the offset slope distance on the fill side of centreline.

## *Additions to clearing width*

### *Compensate for surfacing or ballasting material:*

Before selecting the appropriate unstabilized subgrade width table, compensate for the thickness of surfacing or ballasting material anticipated to be placed over the unstabilzed subgrade surface. For example, where surfacing material is needed to provide a finished road-running surface, select a wider unstabilized subgrade width when determining the clearing width from the tables in this appendix. For every 0.3 m of surfacing depth, allow for an additional 1.0 m of unstabilized subgrade width.

For example, to obtain a 4 m wide finished road-running surface on subgrade soils that will require a 0.3 m thickness of gravel, select Table A5.2 (5 m wide unstabilized subgrade).

*Compensate for other requirements:*
Calculate the extra width required for turnouts, sight distance, snow removal, slash disposal, etc. required on the fill side of road centreline. To determine the lower clearing width boundary, add this extra width to the offset slope distance (fill side of centreline) given in the tables.

For example, if winter use of the road will require snow ploughing, the standing timber should be at least 4 m or more away from the road shoulder. Since the tables will only provide for a minimum of 3 m from the road shoulder to the lower clearing width boundary, simply add the additional 1 or 2 m to the offset slope distance. Where natural side slope angles are greater than 20% the extra width allowance should be converted to a slope distance, rounded up to the nearest metre, and then added to the offset slope distance determined from the tables.

**Tables A5.1 to A5.7:** Offset slope distances in metres from road centreline to upper (cut side) clearing width boundary and lower (fill side) clearing width boundary.

### Table A5.1 -- Unstabilized Subgrade Width = 4 m

| NATURAL SIDE SLOPE ANGLE | FILL SLOPE ANGLE | | | CUT SLOPE ANGLE | | | | |
|---|---|---|---|---|---|---|---|---|
| % | 1H : 1V | 1-1/2H : 1V | 2H : 1V | 1/4H : 1V | 3/4H : 1V | 1H : 1V | 1-1/2H : 1V | 2H : 1V |
| 0-20 | 5 | 5 | 5 | 6 | 7 | 7 | 8 | 10 |
| 21-30 | 5 | 5 | 5 | 6 | 7 | 8 | 9 | 14 |
| 31-35 | 5 | 5 | 5 | 6 | 8 | 8 | 10 | 18 |
| 36-40 | 5 | 5 | 7 | 6 | 8 | 9 | 11 | Use Table B |
| 41-45 | 5 | 5 | Use Table A | 7 | 8 | 10 | 13 | |
| 46-50 | 5 | 7 | | 7 | 9 | 10 | 15 | |
| 51-54 | 5 | 10 | Use alternate construction methods | 7 | 10 | 12 | 26 | Use alternate construction methods |
| 55-57 | 5 | 13 | | 7 | 10 | 12 | 34 | |
| 58-60 | 5 | 19 | | 7 | 10 | 13 | 48 | |

### Table A5.2 -- Unstabilized Subgrade Width = 5 m

| NATURAL SIDE SLOPE ANGLE | FILL SLOPE ANGLE | | | CUT SLOPE ANGLE | | | | |
|---|---|---|---|---|---|---|---|---|
| % | 1H : 1V | 1-1/2H : 1V | 2H : 1V | 1/4H : 1V | 3/4H : 1V | 1H : 1V | 1-1/2H : 1V | 2H : 1V |
| 0-20 | 5 | 5 | 5 | 7 | 7 | 8 | 9 | 11 |
| 21-30 | 5 | 5 | 6 | 7 | 8 | 9 | 10 | 16 |
| 31-35 | 5 | 5 | 8 | 7 | 8 | 9 | 11 | 20 |
| 36-40 | 5 | 6 | 10 | 7 | 9 | 10 | 12 | Use Table B |
| 41-45 | 5 | 7 | Use Table A | 7 | 9 | 11 | 14 | |
| 46-50 | 5 | 9 | | 7 | 10 | 12 | 17 | |
| 51-54 | 5 | 12 | Use alternate construction methods | 7 | 10 | 13 | 29 | Use alternate construction methods |
| 55-57 | 5 | 16 | | 7 | 11 | 14 | 37 | |
| 58-60 | 6 | 23 | | 8 | 11 | 15 | 54 | |

### Table A5.3 -- Unstabilized Subgrade Width = 6 m

| NATURAL SIDE SLOPE ANGLE | FILL SLOPE ANGLE | | | CUT SLOPE ANGLE | | | | |
|---|---|---|---|---|---|---|---|---|
| % | 1H : 1V | 1-1/2H : 1V | 2H : 1V | 1/4H : 1V | 3/4H : 1V | 1H : 1V | 1-1/2H : 1V | 2H : 1V |
| 0-20 | 6 | 6 | 6 | 7 | 8 | 9 | 10 | 12 |
| 21-30 | 6 | 6 | 6 | 7 | 9 | 10 | 11 | 17 |
| 31-35 | 6 | 6 | 8 | 7 | 9 | 10 | 12 | 22 |
| 36-40 | 6 | 7 | 13 | 8 | 9 | 11 | 14 | Use Table B |
| 41-45 | 6 | 9 | Use Table A | 8 | 10 | 12 | 16 | |
| 46-50 | 6 | 11 | | 8 | 10 | 13 | 18 | |
| 51-54 | 7 | 15 | Use alternate construction methods | 8 | 11 | 14 | 32 | Use alternate construction methods |
| 55-57 | 7 | 19 | | 8 | 12 | 15 | 41 | |
| 58-60 | 8 | 28 | | 8 | 12 | 16 | 60 | |

## Table A5.4 -- Unstabilized Subgrade Width = 7 m

| NATURAL SIDE SLOPE ANGLE | FILL SLOPE ANGLE | | | CUT SLOPE ANGLE | | | | |
|---|---|---|---|---|---|---|---|---|
| % | 1H : 1V | 1-1/2H : 1V | 2H : 1V | 1/4H : 1V | 3/4H : 1V | 1H : 1V | 1-1/2H : 1V | 2H : 1V |
| 0-20 | 7 | 7 | 7 | 8 | 9 | 9 | 10 | 13 |
| 21-30 | 7 | 7 | 8 | 8 | 9 | 10 | 12 | 19 |
| 31-35 | 7 | 7 | 10 | 8 | 10 | 11 | 13 | Use Table B |
| 36-40 | 7 | 8 | Use Table A | 8 | 10 | 12 | 14 | |
| 41-45 | 7 | 11 | | 8 | 11 | 12 | 16 | |
| 46-50 | 7 | 14 | | 8 | 11 | 14 | 20 | |
| 51-54 | 8 | 18 | Use alternate construction methods | 9 | 12 | 15 | 35 | Use alternate construction methods |
| 55-57 | 8 | 23 | | 9 | 13 | 16 | 44 | |
| 58-60 | 9 | 33 | | 9 | 13 | 17 | | |

## Table A5.5 -- Unstabilized Subgrade Width = 8 m

| NATURAL SIDE SLOPE ANGLE | FILL SLOPE ANGLE | | | CUT SLOPE ANGLE | | | | |
|---|---|---|---|---|---|---|---|---|
| % | 1H : 1V | 1-1/2H : 1V | 2H : 1V | 1/4H : 1V | 3/4H : 1V | 1H : 1V | 1-1/2H : 1V | 2H : 1V |
| 0-20 | 7 | 7 | 7 | 8 | 9 | 10 | 11 | 14 |
| 21-30 | 7 | 7 | 9 | 8 | 10 | 11 | 12 | 20 |
| 31-35 | 7 | 8 | 11 | 8 | 10 | 12 | 14 | Use Table B |
| 36-40 | 7 | 10 | Use Table A | 8 | 11 | 13 | 16 | |
| 41-45 | 8 | 12 | | 9 | 11 | 14 | 18 | |
| 46-50 | 8 | 16 | | 9 | 12 | 15 | 22 | |
| 51-54 | 9 | 21 | Use alternate construction methods | 10 | 13 | 17 | 38 | Use alternate construction methods |
| 55-57 | 10 | 27 | | 10 | 14 | 18 | 49 | |
| 58-60 | 11 | 39 | | 10 | 14 | 19 | | |

## Table A5.6 -- Unstabilized Subgrade Width = 9 m

| NATURAL SIDE SLOPE ANGLE | FILL SLOPE ANGLE | | | CUT SLOPE ANGLE | | | | |
|---|---|---|---|---|---|---|---|---|
| % | 1H : 1V | 1-1/2H : 1V | 2H : 1V | 1/4H : 1V | 3/4H : 1V | 1H : 1V | 1-1/2H : 1V | 2H : 1V |
| 0-20 | 8 | 8 | 8 | 9 | 10 | 11 | 11 | 14 |
| 21-30 | 8 | 8 | 10 | 9 | 11 | 12 | 13 | 21 |
| 31-35 | 8 | 10 | 13 | 9 | 11 | 13 | 15 | Use Table B |
| 36-40 | 8 | 12 | Use Table A | 9 | 12 | 14 | 17 | |
| 41-45 | 9 | 15 | | 10 | 12 | 15 | 20 | |
| 46-50 | 10 | 19 | | 10 | 13 | 16 | 23 | |
| 51-54 | 10 | 24 | Use alternate construction methods | 10 | 14 | 18 | 41 | Use alternate construction methods |
| 55-57 | 11 | 31 | | 10 | 15 | 19 | 53 | |
| 58-60 | 12 | 45 | | 11 | 16 | 20 | | |

**Tables A5.1 to A5.7:** Offset slope distances in metres from road centreline to upper (cut side) clearing width boundary and lower (fill side) clearing width boundary.

### Table A5.1 -- Unstabilized Subgrade Width = 4 m

| NATURAL SIDE SLOPE ANGLE | FILL SLOPE ANGLE | | | CUT SLOPE ANGLE | | | | |
|---|---|---|---|---|---|---|---|---|
| % | 1H : 1V | 1-1/2H : 1V | 2H : 1V | 1/4H : 1V | 3/4H : 1V | 1H : 1V | 1-1/2H : 1V | 2H : 1V |
| 0-20 | 5 | 5 | 5 | 6 | 7 | 7 | 8 | 10 |
| 21-30 | 5 | 5 | 5 | 6 | 7 | 8 | 9 | 14 |
| 31-35 | 5 | 5 | 5 | 6 | 8 | 8 | 10 | 18 |
| 36-40 | 5 | 5 | 7 | 6 | 8 | 9 | 11 | Use Table B |
| 41-45 | 5 | 5 | Use Table A | 7 | 8 | 10 | 13 | |
| 46-50 | 5 | 7 | | 7 | 9 | 10 | 15 | |
| 51-54 | 5 | 10 | Use alternate construction methods | 7 | 10 | 12 | 26 | Use alternate construction methods |
| 55-57 | 5 | 13 | | 7 | 10 | 12 | 34 | |
| 58-60 | 5 | 19 | | 7 | 10 | 13 | 48 | |

### Table A5.2 -- Unstabilized Subgrade Width = 5 m

| NATURAL SIDE SLOPE ANGLE | FILL SLOPE ANGLE | | | CUT SLOPE ANGLE | | | | |
|---|---|---|---|---|---|---|---|---|
| % | 1H : 1V | 1-1/2H : 1V | 2H : 1V | 1/4H : 1V | 3/4H : 1V | 1H : 1V | 1-1/2H : 1V | 2H : 1V |
| 0-20 | 5 | 5 | 5 | 7 | 7 | 8 | 9 | 11 |
| 21-30 | 5 | 5 | 6 | 7 | 8 | 9 | 10 | 16 |
| 31-35 | 5 | 5 | 8 | 7 | 8 | 9 | 11 | 20 |
| 36-40 | 5 | 6 | 10 | 7 | 9 | 10 | 12 | Use Table B |
| 41-45 | 5 | 7 | Use Table A | 7 | 9 | 11 | 14 | |
| 46-50 | 5 | 9 | | 7 | 10 | 12 | 17 | |
| 51-54 | 5 | 12 | Use alternate construction methods | 7 | 10 | 13 | 29 | Use alternate construction methods |
| 55-57 | 5 | 16 | | 7 | 11 | 14 | 37 | |
| 58-60 | 6 | 23 | | 8 | 11 | 15 | 54 | |

### Table A5.3 -- Unstabilized Subgrade Width = 6 m

| NATURAL SIDE SLOPE ANGLE | FILL SLOPE ANGLE | | | CUT SLOPE ANGLE | | | | |
|---|---|---|---|---|---|---|---|---|
| % | 1H : 1V | 1-1/2H : 1V | 2H : 1V | 1/4H : 1V | 3/4H : 1V | 1H : 1V | 1-1/2H : 1V | 2H : 1V |
| 0-20 | 6 | 6 | 6 | 7 | 8 | 9 | 10 | 12 |
| 21-30 | 6 | 6 | 6 | 7 | 9 | 10 | 11 | 17 |
| 31-35 | 6 | 6 | 8 | 7 | 9 | 10 | 12 | 22 |
| 36-40 | 6 | 7 | 13 | 8 | 9 | 11 | 14 | Use Table B |
| 41-45 | 6 | 9 | Use Table A | 8 | 10 | 12 | 16 | |
| 46-50 | 6 | 11 | | 8 | 10 | 13 | 18 | |
| 51-54 | 7 | 15 | Use alternate construction methods | 8 | 11 | 14 | 32 | Use alternate construction methods |
| 55-57 | 7 | 19 | | 8 | 12 | 15 | 41 | |
| 58-60 | 8 | 28 | | 8 | 12 | 16 | 60 | |

### Table A5.4 -- Unstabilized Subgrade Width = 7 m

| NATURAL SIDE SLOPE ANGLE | FILL SLOPE ANGLE | | | CUT SLOPE ANGLE | | | | |
|---|---|---|---|---|---|---|---|---|
| **%** | **1H : 1V** | **1-1/2H : 1V** | **2H : 1V** | **1/4H : 1V** | **3/4H : 1V** | **1H : 1V** | **1-1/2H : 1V** | **2H : 1V** |
| 0-20 | 7 | 7 | 7 | 8 | 9 | 9 | 10 | 13 |
| 21-30 | 7 | 7 | 8 | 8 | 9 | 10 | 12 | 19 |
| 31-35 | 7 | 7 | 10 | 8 | 10 | 11 | 13 | Use Table B |
| 36-40 | 7 | 8 | Use Table A | 8 | 10 | 12 | 14 | |
| 41-45 | 7 | 11 | | 8 | 11 | 12 | 16 | |
| 46-50 | 7 | 14 | | 8 | 11 | 14 | 20 | |
| 51-54 | 8 | 18 | Use alternate construction methods | 9 | 12 | 15 | 35 | Use alternate construction methods |
| 55-57 | 8 | 23 | | 9 | 13 | 16 | 44 | |
| 58-60 | 9 | 33 | | 9 | 13 | 17 | | |

### Table A5.5 -- Unstabilized Subgrade Width = 8 m

| NATURAL SIDE SLOPE ANGLE | FILL SLOPE ANGLE | | | CUT SLOPE ANGLE | | | | |
|---|---|---|---|---|---|---|---|---|
| **%** | **1H : 1V** | **1-1/2H : 1V** | **2H : 1V** | **1/4H : 1V** | **3/4H : 1V** | **1H : 1V** | **1-1/2H : 1V** | **2H : 1V** |
| 0-20 | 7 | 7 | 7 | 8 | 9 | 10 | 11 | 14 |
| 21-30 | 7 | 7 | 9 | 8 | 10 | 11 | 12 | 20 |
| 31-35 | 7 | 8 | 11 | 8 | 10 | 12 | 14 | Use Table B |
| 36-40 | 7 | 10 | Use Table A | 8 | 11 | 13 | 16 | |
| 41-45 | 8 | 12 | | 9 | 11 | 14 | 18 | |
| 46-50 | 8 | 16 | | 9 | 12 | 15 | 22 | |
| 51-54 | 9 | 21 | Use alternate construction methods | 10 | 13 | 17 | 38 | Use alternate construction methods |
| 55-57 | 10 | 27 | | 10 | 14 | 18 | 49 | |
| 58-60 | 11 | 39 | | 10 | 14 | 19 | | |

### Table A5.6 -- Unstabilized Subgrade Width = 9 m

| NATURAL SIDE SLOPE ANGLE | FILL SLOPE ANGLE | | | CUT SLOPE ANGLE | | | | |
|---|---|---|---|---|---|---|---|---|
| **%** | **1H : 1V** | **1-1/2H : 1V** | **2H : 1V** | **1/4H : 1V** | **3/4H : 1V** | **1H : 1V** | **1-1/2H : 1V** | **2H : 1V** |
| 0-20 | 8 | 8 | 8 | 9 | 10 | 11 | 11 | 14 |
| 21-30 | 8 | 8 | 10 | 9 | 11 | 12 | 13 | 21 |
| 31-35 | 8 | 10 | 13 | 9 | 11 | 13 | 15 | Use Table B |
| 36-40 | 8 | 12 | Use Table A | 9 | 12 | 14 | 17 | |
| 41-45 | 9 | 15 | | 10 | 12 | 15 | 20 | |
| 46-50 | 10 | 19 | | 10 | 13 | 16 | 23 | |
| 51-54 | 10 | 24 | Use alternate construction methods | 10 | 14 | 18 | 41 | Use alternate construction methods |
| 55-57 | 11 | 31 | | 10 | 15 | 19 | 53 | |
| 58-60 | 12 | 45 | | 11 | 16 | 20 | | |

## Table A5.7 -- Unstabilized Subgrade Width = 10 m

| NATURAL SIDE SLOPE ANGLE | FILL SLOPE ANGLE | | | CUT SLOPE ANGLE | | | | |
|---|---|---|---|---|---|---|---|---|
| % | 1H : 1V | 1-1/2H : 1V | 2H : 1V | 1/4H : 1V | 3/4H : 1V | 1H : 1V | 1-1/2H : 1V | 2H : 1V |
| 0-20 | 8 | 8 | 8 | 9 | 10 | 11 | 12 | 15 |
| 21-30 | 8 | 9 | 11 | 9 | 11 | 12 | 14 | Use Table B |
| 31-35 | 8 | 11 | 15 | 10 | 12 | 13 | 16 | |
| 36-40 | 9 | 13 | Use Table A | 10 | 12 | 14 | 18 | |
| 41-45 | 10 | 16 | | 10 | 13 | 16 | 21 | |
| 46-50 | 11 | 21 | | 10 | 14 | 17 | 25 | |
| 51-54 | 12 | 27 | Use alternate construction methods | 11 | 15 | 19 | 45 | Use alternate construction methods |
| 55-57 | 13 | 36 | | 11 | 16 | 21 | 58 | |
| 58-60 | 14 | 50 | | 11 | 17 | 22 | | |

**Tables A & B:** These following two tables are referenced in Tables A5.1 to A5.7

### Table A

Offset slope distance for **2H:1V fill slope** angles

| NATURAL SIDE SLOPE ANGLE | Unstabilized Subgrade Width | | | | | | |
|---|---|---|---|---|---|---|---|
| % | 4 m | 5 m | 6 m | 7 m | 8 m | 9 m | 10 m |
| 36-38 | Use tables above | | | 13 | 15 | 17 | 19 |
| 40 | | | | 16 | 18 | 21 | 23 |
| 42 | 9 | 13 | 16 | 19 | 22 | 25 | 28 |
| 44 | 12 | 17 | 22 | 26 | 30 | 34 | 37 |
| 46 | 20 | 28 | 35 | 41 | 46 | 50 | |
| 48 | 44 | Use alternate construction methods | | | | | |

### Table B

Offset slope distance for **2H:1V cut slope** angles

| NATURAL SIDE SLOPE ANGLE | Unstabilized Subgrade Width | | | | | | |
|---|---|---|---|---|---|---|---|
| % | 4 m | 5 m | 6 m | 7 m | 8 m | 9 m | 10 m |
| 21-25 | Use tables above | | | | | | 17 |
| 26-28 | | | | | | | 20 |
| 30 | | | | | | | 22 |
| 32 | | | | 20 | 21 | 23 | 24 |
| 34 | | | | 22 | 24 | 25 | 27 |
| 36 | 19 | 21 | 23 | 25 | 27 | 29 | 31 |
| 38 | 22 | 24 | 27 | 29 | 32 | 34 | 36 |
| 40 | 26 | 29 | 32 | 35 | 38 | 41 | |
| 42 | 32 | 36 | 39 | 43 | 47 | 50 | |
| 44 | 42 | 52 | Use alternate construction methods | | | | |

## Table A5.7 -- Unstabilized Subgrade Width = 10 m

| NATURAL SIDE SLOPE ANGLE | FILL SLOPE ANGLE | | | CUT SLOPE ANGLE | | | | |
|---|---|---|---|---|---|---|---|---|
| **%** | **1H : 1V** | **1-1/2H : 1V** | **2H : 1V** | **1/4H : 1V** | **3/4H : 1V** | **1H : 1V** | **1-1/2H : 1V** | **2H : 1V** |
| 0-20 | 8 | 8 | 8 | 9 | 10 | 11 | 12 | 15 |
| 21-30 | 8 | 9 | 11 | 9 | 11 | 12 | 14 | Use Table B |
| 31-35 | 8 | 11 | 15 | 10 | 12 | 13 | 16 | |
| 36-40 | 9 | 13 | Use Table A | 10 | 12 | 14 | 18 | |
| 41-45 | 10 | 16 | | 10 | 13 | 16 | 21 | |
| 46-50 | 11 | 21 | | 10 | 14 | 17 | 25 | |
| 51-54 | 12 | 27 | Use alternate construction methods | 11 | 15 | 19 | 45 | Use alternate construction methods |
| 55-57 | 13 | 36 | | 11 | 16 | 21 | 58 | |
| 58-60 | 14 | 50 | | 11 | 17 | 22 | | |

**Tables A & B:** These following two tables are referenced in Tables A5.1 to A5.7

### Table A

Offset slope distance for **2H:1V fill slope** angles

| NATURAL SIDE SLOPE ANGLE | Unstabilized Subgrade Width | | | | | | |
|---|---|---|---|---|---|---|---|
| % | 4 m | 5 m | 6 m | 7 m | 8 m | 9 m | 10 m |
| 36-38 | Use tables above | | | 13 | 15 | 17 | 19 |
| 40 | | | | 16 | 18 | 21 | 23 |
| 42 | 9 | 13 | 16 | 19 | 22 | 25 | 28 |
| 44 | 12 | 17 | 22 | 26 | 30 | 34 | 37 |
| 46 | 20 | 28 | 35 | 41 | 46 | 50 | |
| 48 | 44 | Use alternate construction methods | | | | | |

### Table B

Offset slope distance for **2H:1V cut slope** angles

| NATURAL SIDE SLOPE ANGLE | Unstabilized Subgrade Width | | | | | | |
|---|---|---|---|---|---|---|---|
| % | 4 m | 5 m | 6 m | 7 m | 8 m | 9 m | 10 m |
| 21-25 | Use tables above | | | | | | 17 |
| 26-28 | | | | | | | 20 |
| 30 | | | | | | | 22 |
| 32 | | | | 20 | 21 | 23 | 24 |
| 34 | | | | 22 | 24 | 25 | 27 |
| 36 | 19 | 21 | 23 | 25 | 27 | 29 | 31 |
| 38 | 22 | 24 | 27 | 29 | 32 | 34 | 36 |
| 40 | 26 | 29 | 32 | 35 | 38 | 41 | |
| 42 | 32 | 36 | 39 | 43 | 47 | 50 | |
| 44 | 42 | 52 | Use alternate construction methods | | | | |

# Appendix 6. Sample road inspection and maintenance report

## ROAD INSPECTION AND MAINTENANCE REPORT

| | | | |
|---|---|---|---|
| *Date: Y M D* | *File No.* | *Road Name* | *Road Project No.* |
| *Forest Region* | *Forest District* | *Local Road Name* | *Local Road No.* |

| | | | | |
|---|---|---|---|---|
| *Licensee or Agency* | *Forest Licence or TSL* | *Road Permit or CP No.* | *Amendment No. or Block No.* | *Road Section No.* |

***GPS Co-ordinates at Start of Inspection:***

***Other Tenure Comments:***

***Inspect for the following items to ensure integrity of the road:***

| **Structural Integrity:** | | **Drainage Systems:** | |
|---|---|---|---|
| • Tension cracks visible | SI-01 | • Natural drainage patterns maintained | DS-01 |
| • Cutslope failures | SI-02 | • Culverts clear and working | DS-02 |
| • Fill slope failures | SI-02 | • Culverts washed out | DS-03 |
| • Slides or mass land movements | SI-04 | • Culvert and /or ends damaged | DS-04 |
| • Shoulder slumps | SI-05 | • Culvert markers | DS-05 |
| • Frost boils | SI-06 | • Adequate fill over culverts | DS-06 |
| • Subgrade unable to support wheel loads | SI-07 | • Ditch blocks in place and working | DS-07 |
| • Washouts | SI-08 | • Adequate cross-drain culverts | DS-08 |
| **Road Surface:** | | • Undersized cross-drain or stream culverts | DS-09 |
| • Depth of surface material adequate | RS-01 | • Ditches scoured | DS-10 |
| • Potholes | RS-02 | • Ditches unobstructed (debris, grass, vegetation) | DS-11 |
| • Washboard | RS-03 | • Ditchline sloughing | DS-12 |
| • Rutting from vehicle wheels | RS-04 | **Safe Fish Passage:** | |
| • Windrows present | RS-05 | • Fish stream culvert inlets and outlets | FP-01 |
| • Damage from cattle | RS-06 | • Inadequate structure | FP-02 |
| • Road surface erosion | RS-07 | **Road Safety:** | |
| • Sediment transport from road prism | RS-08 | • Site distances | SA-01 |
| • Dust | RS-09 | • Brushing | SA-02 |
| **Bridge Surface** | | • Snags and danger trees | SA-03 |
| • Waterway opening free of logs and debris | BS-01 | • Other road hazards (loose rocks, stumps, etc.) | SA-04 |
| • Bearing surfaces free of gravel and dirt | BS-02 | • Traffic control signs | SA-04 |
| • Wood stringers free of dirt accumulations | BS-03 | • Road radio frequencies posted | SA-06 |
| • Running planks missing or damaged; nails protruding | BS-04 | | |
| • Damaged guide rails or curbs | BS-05 | | |
| • Gravel build-up on bridge deck | BS-06 | | |

| Location (km) or GPS Co-ord | Comments and/or Code | Remedial Works to Be Completed by Date: | Remedial Works Completed Date: |
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***Additional Comments Regarding Inspection:***

***Comments Regarding Remedial Actions:***

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ***Sign-off of Inspection:*** | | | | | | | |
| ***Inspector*** | ***Y*** | ***M*** | ***D*** | ***Licensee or Agency Specialist*** | Y | M | D |
| ***Sign-off of Completion of Remedial Maintenance Works:*** | | | | | | | |
| ***Inspector*** | ***Y*** | ***M*** | ***D*** | ***Licensee or Agency Specialist*** | Y | M | D |

# Appendix 7. Sample road deactivation inspection report

**ROAD DEACTIVATION INSPECTION REPORT**

| | | | |
|---|---|---|---|
| ***Date: Y M D*** | ***File No.*** | ***Road Name*** | ***Road Project No.*** |
| ***Forest Region*** | ***Forest District*** | ***Local Road Name*** | ***Local Road No.*** |

| | | | | |
|---|---|---|---|---|
| ***Licensee or Agency*** | ***Forest Licence or TSL*** | ***Road Permit or CP No.*** | ***Amendment No. or Block No.*** | ***Road Section No.*** |

***GPS Co-ordinates at Start of Inspection:***

***Deactivation Prescription Information***

| | | | |
|---|---|---|---|
| *Deactivation Level:* | *Temporary:* ☐ | *Semi-Permanent:* ☐ | *Permanent:* ☐ |
| *Type of Vehicle Usage:* | *4 WD:* ☐ | *ATV:* ☐ | *None:* ☐ |

*Date Deactivation Work Completed:*

*Date That Area Was Grass Seeded or Planted:*

***Inspect for the following items to ensure integrity of the road:***

| **Vehicle Usage** | | **Road Prism and Water Management** | |
|---|---|---|---|
| • Road still passable for intended vehicle use | DV-01 | • Re-vegetation satisfactory | DW-01 |
| **Stability** | | • Road surface erosion | DW-02 |
| • Pullback failures | DS-01 | • Sediment transport form road prism | DW-03 |
| • Cutslope failures | DS-02 | • Cross-ditches functional | DW-04 |
| • Fill slope failures | DS-03 | • Ditch blocks functional | DW-05 |
| • Slide or mass land movements | DS-04 | • Excessive ditch sediment transport | DW-06 |
| **Road Safety** | | • Ditches unobstructed (debris, grass, vegetation) | DW-07 |
| • Deactivation warning signs in place | DR-01 | • Bridges and stream culverts functional | DW-08 |
| • Snags and danger trees felled | DR-02 | • Stream crossing structures allow for safe fish passage (constructed or modified after June 15, 1995) | DW-09 |
| • Other road hazards present (loose rocks, stumps, etc.) | DR-03 | | |

| **Location (km) or GPS Co-ord.** | **Comments and/or Code** | **Remedial Works to Be Completed by Date:** | **Remedial Works Completed Date:** |
|---|---|---|---|
| | | | |
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| Location (km) or GPS Co-ord. | Comments and/or Code | Remedial Works to Be Completed by Date: | Remedial Works Completed Date: |
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***Additional Inspection Comments:***

***Comments Regarding Remedial Actions:***

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ***Sign-off of Inspection:*** | | | | | | | |
| ***Inspector*** | *Y* | *M* | *D* | *Licensee or Agency Specialist* | *Y* | *M* | *D* |
| ***Sign-off of Completion of Remedial Works:*** | | | | | | | |
| ***Inspector*** | *Y* | *M* | *D* | *Licensee or Agency Specialist* | *Y* | *M* | *D* |

# Appendix 8. Example field data form for deactivation field assessments

Road name / Road permit: ______________________

Date: ______________________

Recorded by: ______________________

Weather conditions: ______________________

Page: _____ of _____

| Road station: start/end | Estimated construction difficulty (optional) | Prescription symbol for deactivation technique | Comments | Terrain / soils | Natural ∠ upslope (% ) | Natural ∠ downslope (%) | Road gradient (%) | Road width (m) | Fill slope length (m) | Fill slope angle (%) | Cut slope height (m) | Cut slope angle (%) | Stability/ surface erosion problems? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

## Legend:

| Data Entry Field | Description |
|---|---|
| Road station: start/end | Road station (e.g., 1+250) |
| Estimated construction difficulty and/or estimated equipment time | Optional data entry field: If necessary, give relative ranking of difficulty to carry out the major works prescribed, and or estimated equipment time to carry out the prescribed action. This information may be useful to estimate unit costs (e.g., easy, average, difficult) |
| Prescription symbol for deactivation technique | Examples: X (cross-ditch), RMC (remove metal culvert), P9 (pull 9 m). Symbols are often combined at specific locations. For example, at a single culvert location the deactivation prescription may be "Remove metal culvert" and "cross-ditch" |
| Comments | Important observations, which may include, for example: areas of seepage; width/length of tension cracks; hazard/consequence/risk of damage to neighbouring resources; requirement for professional field reviews; armouring requirements; source of armour; current motor vehicle access conditions; locations where access must be restored; locations of required benching and ramping for road fill pullback; worker safety concerns; condition of pipe and wood box culverts; condition of bridges; evidence of scour on road; evidence of unstable cuts/fills; landslides; vegetative cover; composition of cut and road fill materials; evidence of woody debris in road fill; evidence of temporary woody debris-supported materials along toe of road fill; location of large gravel pits; landings, etc. |
| Terrain/soils | Surficial material types of natural terrain (colluvium, bedrock, till, etc.) and texture of natural soils (sand, silt, sand and gravel, etc.) |
| Natural ∠ Upslope (% ) | Slope angle of natural terrain above road cut |
| Natural ∠ Downslope (%) | Slope angle of natural terrain below toe of road fill |
| Road gradient (%) | Average gradient of road |
| Road width (m) | Width of road |
| Fill slope length (m) | Length of fill slope below outer edge of road |
| Fill slope angle (%) | Slope angle of fill slope |
| Cut slope height (m) | Height of cut slope |
| Cut slope angle (%) | Slope angle of cut slope |
| Stability/surface erosion | Examples: TC (tension crack), SE (surface erosion), FF (fill failure), LS (landslide) |

# Appendix 9. Example road deactivation prescription content requirements

Examples are presented below showing the linkage between various site and project conditions and the minimum content of a road deactivation prescription.

**Example 1:** A road is prescribed for semi-permanent deactivation with 4-wheel drive vehicle access. The road traverses gentle terrain with no landslide hazard. There are a few crossings of S6 streams, and some cross-drain culverts on the road. The risk of damage to adjacent resources is low or minimal. Deactivation measures are limited to water management techniques (such as cross-ditches, waterbars, and back-up of some stream culverts) and revegetation of exposed soils using a suitable grass seed and legume mixture.

- *Example Prescription Content Requirements*: For this project, a scale topographic map showing the locations of recommended actions corresponding to the chainages of field markings may be sufficient for communication of the required works to field crews (and review and approval by the district manager, if required).

**Example 2:** A road is prescribed for semi-permanent deactivation with 4-wheel drive vehicle access. The road traverses gentle to moderate terrain with no landslide hazard. There are many culvert and bridge crossings of S5 and S4 streams, and many cross-drain culverts along the road. The soils are fine-grained and prone to erosion. The area is in a wet belt. The risk of sediment transport to aquatic resources and aquatic habitat from existing sediment sources is high. Deactivation measures include water management techniques such as cross-ditches, waterbars, removal or back-up of cross-drain culverts, and removal or back-up of stream culverts, and other measures such as repair of bridges and revegetation of exposed soils using a suitable grass seed and legume mixture.

- *Example Prescription Content Requirements*: In this case, the basic minimum requirement of a deactivation prescription would be a 1:5000 scale map (or other suitable scale) showing the locations of the actions corresponding to the chainages of field markings, and a tabular summary (spreadsheet) to accompany and complement the map. The tabular summary should provide more detailed information such as general site conditions, the size of existing culverts and bridges, sediment transport hazards and consequences, and methods to control sediment transport, including the measured chainages along the road and the corresponding actions. In this case, the prescription should clearly identify the fish streams and the timing windows for working in and about a stream, as developed and provided by a designated environment official.

**Example 3:** A road is prescribed for semi-permanent deactivation with 4-wheel drive vehicle access. The road is located on a mid-slope, and traverses steep terrain and areas of moderate to high likelihood of landslides. (**Note:** A qualified registered professional must prepare a deactivation prescription where the road crosses areas with a moderate or high likelihood of landslides, as determined by a terrain stability field assessment [TSFA].) There are visual indicators of road fill instability, surface soil erosion, and previous road fill washouts along the road. The road is located in a wet belt, and receives high annual precipitation. The road crosses many deeply incised S5 streams contained in gullies tributary to an S2 stream downslope of the road. Deactivation measures include water management techniques such as cross-ditches, and removal or back-up of stream culverts, long segments of partial road fill pullback to maintain motor vehicle access, and revegetation of exposed soils using a suitable grass seed and legume mixture. There is an existing high risk of potential damage to public utilities, a highway, and the S2 stream from potential fill slope failures.

- *Example Prescription Content Requirements*: This is a more complex project, involving deactivation prescriptions for unstable terrain. Reporting may include more detailed observations and assessment of terrain stability. In this case, the basic minimum requirement of a deactivation prescription would include a 1:5000 scale map showing the locations of the actions corresponding to the chainages of field markings, a tabular summary (spreadsheet) to accompany and complement the map, and a detailed letter or report. The prescription should clearly identify the timing windows for working in and about streams that are tributary to the S2 stream, developed and provided by a designated environment official. The prescription should also specify the need for any professional field reviews during the deactivation work.

# Appendix 10. Landslide risk analysis

## Introduction

This appendix provides:

- an example of a procedure for carrying out a qualitative landslide risk analysis, including an example qualitative landslide risk matrix (Table A10.1).
- an example of a qualitative landslide hazard table (Table A10.2)
- examples of qualitative landslide consequence tables (Tables A10.3–A10.11)

**Landslide risk analysis** is a systematic use of information to determine the landslide hazard (likelihood of landslide occurrence) and the consequence of a landslide at a particular site, thereby allowing an estimate of the risk to adjacent resources from a landslide occurrence.

**Notes:**
The examples of the qualitative landslide hazard table, landslide consequence tables, and landslide risk matrix provided are for illustration only and should not be considered a procedural standard. The tables and matrix should be modified, or a different risk-ranking method that varies in detail and complexity, should be adapted to suit site-specific requirements.

Qualitative landslide risk analysis satisfies most forestry practice needs where relative risk rankings are sufficient to provide guidance for decision making. This method of risk analysis, however, has limitations and in some circumstances it may be advantageous to use a quantitative landslide risk analysis method.

## Landslide risk

**Landslide risk** = Landslide hazard × Landslide consequence
= Likelihood of landslide occurrence × [(Element at risk) × (Vulnerability of that element at risk from a landslide)]

Table A10.1 is an example of a qualitative landslide risk matrix for a specific element at risk. It combines a relative landslide hazard rating and a relative landslide consequence rating that represents the vulnerability of that element at risk. The term "vulnerability" refers to the fact that an element at risk may be exposed to different degrees of damage or loss from a landslide.

Table A10.1 uses a 5 × 3 matrix, consisting of five qualitative ratings of landslide hazards (VH, H, M, L, and VL) described in Table A10.2, and three qualitative ratings of landslide consequences (H, M, L) described in Tables A10.3–A10.11.

**Table A10.1.** Example of a qualitative risk matrix.

| Risk of Damage to Element at Risk | | Landslide Consequence | | |
|---|---|---|---|---|
| | | **Low** | **Mod** | **High** |
| **Landslide Hazard** | **Very Low** | *VL* | *VL* | *L* |
| | **Low** | *VL* | *L* | *M* |
| | **Mod** | *L* | *M* | *H* |
| | **High** | *M* | *H* | *VH* |
| | **Very High** | *H* | *VH* | *VH* |

## Landslide hazard

Landslide hazard is the likelihood of a particular landslide occurring. It is dependent on the type and magnitude of the landslide of significance for a specified element at risk. The **landslide of significance** is the smallest landslide that could adversely affect the element at risk.

For example, if the element at risk is a fish stream, the landslide of significance is the smallest landslide that could reach, and adversely affect, the stream. The landslide of significance usually has the greatest probability of occurrence of any landslide to affect the element at risk. For a specific site, landslides that are smaller or larger than the landslide of significance could occur. For example, a smaller landslide event would have a greater likelihood of occurrence compared to the landslide of significance, but would usually have no adverse effect on a fish stream. Similarly, a larger landslide event would have a much smaller chance of occurring compared to the landslide of significance, but would result in greater damage and therefore have an adverse effect on a fish stream.

Different elements at risk often have different landslides of significance. It is possible that the same element at risk could be potentially subject to two or more different types of landslides at the same time, and therefore could be subject to two or more different landslide hazards. Assuming the same type of landslide, the landslides of significance for different elements at risk could be quite different, and therefore the hazards could be quite different.

Description of a landslide hazard for forestry purposes should include an estimate of landslide characteristics, such as:

- the likely path of a landslide event
- the dimensions of the transportation and deposition areas

- the type of materials involved (e.g., source area material type)
- the volumes of material removed and deposited.

In Table A10.2, the **example of range of annual probability** (Column 2) and **example of qualitative description** for a range of annual probability (Column 3) are only included to give users some physical idea of the meaning of the relative qualitative ratings in Column 1.

Additionally, some users may relate better to a 20-year period of time (approximating the life of a logging road) than to an annual probability. For this reason, Column 4 in Table A10.2 provides an **example of range of probability** of landslide occurrence for the landslide of significance for a specific element at risk assuming a 20-year design life. For illustrative purposes, the following example shows that a **Moderate** hazard rating (annual probability [Pa] of 1/100) corresponds to an 18% chance that at least one landslide event will occur in 20 years.

**Example:**

According to probability theory, the long-term probability of occurrence (Px) is related to the annual probability of occurrence (Pa) by the following:

$Px = 1-[1-(1/Pa)]^x$, where Px is the probability of at least one landslide occurring within the specified time period "x" years.

For a service life of 20 years (i.e., x = 20), and a Pa of 1/100,

$$\begin{aligned} P20 &= 1-[1-(1/100)]^{20} \\ &= 0.18 \text{ or } 18\% \end{aligned}$$

This means that there is an 18% chance of the 1 in 100-year event occurring within the 20-year service life of the road. If the service life of the road is doubled to 40 years (i.e., x = 40), the chance of the 1 in 100-year event occurring within the 40-year service life rises to 33%.

## Landslide consequence

Landslide consequence is the product of the element at risk and the vulnerability of that element at risk from a landslide. Tables A10.3–A10.11 are examples of landslide consequence tables that express consequence in terms of three relative qualitative ratings: H, M, and L. In this scheme, if there is no likely consequence, the consequence is assumed to be less than low, or nil, as appropriate. The elements at risk included in these consequence tables include:

| Table | Element at risk |
|---|---|
| Table A10.3 | Human life and bodily harm |
| Table A10.4 | Public and private property (includes building, structure, land, resource, recreational site and resource, cultural heritage feature and value, and other features) |
| Table A10.5 | Transportation system/corridor |
| Table A10.6 | Utility and utility corridor |
| Table A10.7 | Domestic water supply |
| Table A10.8 | Fish habitat |
| Table A10.9 | Wildlife (non-fish) habitat and migration |
| Table A10.10 | Visual resource in scenic area |
| Table A10.11 | Timber value (includes soil productivity) |

## Table A10.2. Example of a qualitative landslide hazard table.

Intended for use in qualitative landslide hazard and risk analyses for terrain stability field assessments, and for preparation of measures to maintain slope stability and road deactivation prescriptions.

**Landslide hazard** is the likelihood of a particular landslide occurring. It is dependent on the type and magnitude of the **landslide of significance** for a specified element at risk. Refer to text for further discussion.

| **Column (1)** **Relative qualitative rating of landslide occurrence** for the landslide of significance for a specific element at risk | **Column (2)** **Example of range of *annual* probability** (Pa) of landslide occurrence for the landslide of significance for a specific element at risk[a,b,c] | **Column (3)** **Example of qualitative description** for range of *annual* probability (Pa)[c] | **Column (4)** **Example of range of probability** of landslide occurrence for the landslide of significance for a specific element at risk[a,c] **(assumes a 20-year design life)** |
|---|---|---|---|
| Very High (VH) | Annual probability (Pa) >1/20 | Pa of 1/20 indicates that a landslide is imminent (or likely to occur frequently) for an existing road, or would occur soon after road construction in the case of new road development, and well within the lifetime of the road. In the case of past landslide activity, landslides occurring within the past 20 years generally have clear and relatively fresh signs of disturbance. | >64% chance that at least one event will occur in 20 years |
| High (H) | Annual probability (Pa) 1/100 to 1/20 | Pa of 1/100 indicates that a landslide can happen (or is probable) within the approximate lifetime of the existing or proposed road. In the case of past landslide activity, landslides occurring between 20 and 100 years are usually identifiable from deposits and vegetation, but may not appear fresh. | 64% chance that at least one event will occur in 20 years |
| Moderate (M) | Annual probability (Pa) 1/500 to 1/100 | Pa of 1/500 indicates that a landslide within a given lifetime of the existing or proposed road is not likely, but possible. In the case of past landslide activity, landslides occurring between 100 and 500 years may not be easily identified. | 18% chance that at least one event will occur in 20 years |
| Low (L) | Annual probability (Pa) 1/2500 to 1/500 | Pa of 1/2500 indicates that the likelihood of a landslide is remote within the lifetime of the road. In the case of past landslide activity, landslides occurring between 500 and 2500 years are difficult to identify. | 4% chance that at least one event will occur in 20 years |
| Very Low (VL) | Annual probability (Pa) <1/2500 | Pa < 1/2500 indicates that the likelihood of a landslide is very remote within the lifetime of the road. | 1% chance that at least one event will occur in 20 years |

(Modified after Resource Inventory Committee 1996)

Notes:
- a. Assume that ranges of probability apply to a 1-km segment of road.
- b. Annual probability (Pa) of 1/100, for example, means an event with an estimated return period of 100 years.
- c. The **example of range of annual probability** (Column 2) and **example of qualitative description** for a range of annual probability (Column 3) are only included to give users some physical idea of the meaning of the relative qualitative ratings in Column 1.

## Tables A10.3–A10.11. Examples of qualitative landslide consequence tables.

Intended for use in qualitative landslide hazard and risk analyses for terrain stability field assessments, and for preparation of measures to maintain slope stability and road deactivation prescriptions.

**Notes:**

- **Consequence** is the product of the element at risk and the vulnerability of that element at risk from a landslide.
- Only a few "examples of factors to consider" are provided. There may be others depending on the scale of assessment and the project and site conditions.
- The tables are **examples only** and would likely change depending on the scale of assessment (temporary spur road, versus permanent mainline, versus secondary road, versus provincial highway, etc.).
- For most elements at risk, only broad values are applied (e.g., utilized building or structure versus abandoned building or structure; active transportation system/corridor versus non-active transportation system/corridor, critical utility, or utility corridor).
- The ratings in the consequence tables for the various elements at risk should not be compared.
- **If there is no likely consequence, consider the consequence <low or nil.**

## Table A10.3. Example of consequences to human life and bodily injury.

Examples of factors to consider:

- Includes forestry workers and the general public.
- Important factors include landslide path, volume, and speed, numbers of individuals affected, likelihood of people being within the landslide path, and their time of exposure.

| Consequence | Examples |
|---|---|
| High | • Loss of life or injury, OR<br>• Constant exposure to moderate or high potential landslide hazard. |
| Moderate | • Intermittent or low exposure to moderate or high potential landslide hazard, OR<br>• Constant exposure to low potential landslide hazard. |
| Low | • Intermittent or low exposure to low potential landslide hazard. |

**Table A10.4.** Example of consequences to public and private property (building, structure, land, resource, recreational site and resource, cultural heritage feature and value, and other features).

Examples of factors to consider:

- Applies where there is no threat to human life or bodily injury. If there is, refer to "Consequences to human life and bodily injury" table.
- Important factors include landslide path, volume, and speed, utilization of building or structure, land and resource present, direct and indirect costs, continuity or duration of any effects, and extent of damage.

| Consequence | Examples |
|---|---|
| High | • Destruction of, or excessive (non-reparable) damage to, utilized building, structure, or cultural heritage feature, OR<br>• Excessive, or continual moderate, adverse effects on land, cultural heritage value, or other resource. |
| Moderate | • Moderate (reparable) damage to utilized building, structure, or cultural heritage feature, OR<br>• Excessive damage (non-reparable) to non-utilized building or structure, or to less significant cultural heritage value, OR<br>• Moderate, or continual minor, adverse effects on land, cultural heritage value, or other resource. |
| Low | • Minor (inconvenient) damage to utilized building, structure, or cultural heritage feature, OR<br>• Moderate (reparable) damage to non-utilized building or structure, or to less significant cultural heritage value, OR<br>• Minor adverse effects on land, cultural heritage value, or other resource. |

## Table A10.5. Example of consequences to transportation system/corridor.

Examples of factors to consider:

- Applies where there is no threat to human life or bodily injury. If there is, refer to "Consequences to human life and bodily injury" table.
- Important factors include landslide path, volume and speed, type of transportation corridor/system, utilization of transportation corridor/system, duration of disruption, availability of alternative routes, direct and indirect costs, and extent of damage.

| Consequence | Examples |
|---|---|
| High | • Destruction of, or extensive (not easily reparable) damage to, active transportation system/corridor, OR<br>• Long-term (> 1 week) disruption to transportation system/corridor. |
| Moderate | • Moderate (easily reparable) damage to active transportation system/corridor, OR<br>• Excessive damage (non-reparable) to non-active transportation system/corridor, OR<br>• Short-term (1 day – 1 week) disruption to transportation system/corridor. |
| Low | • Minor (inconvenient) damage to active transportation system/corridor, OR<br>• Moderate (reparable) damage to non-active transportation system/corridor, OR<br>• Very short (< 1 day) disruption to transportation system/corridor. |

## Table A10.6. Example of consequences to utility and utility corridor.

Examples of factors to consider:

- Applies where there is no threat to human life or bodily injury. If there is, refer to "Consequences to human life and bodily injury" table.
- Important factors include landslide path, volume and speed, type of utility, utilization of (how critical is) utility or utility corridor, duration of disruption, availability of alternative service, direct and indirect costs, and extent of damage.

| Consequence | Examples |
|---|---|
| High | • Destruction of, or extensive (not easily reparable) damage to, critical utility or utility corridor, OR<br>• Long-term (> 1 week) disruption to critical utility or utility corridor. |
| Moderate | • Moderate (easily reparable) damage to critical utility or utility corridor, OR<br>• Excessive damage (non-reparable) to non-critical utility or utility corridor, OR<br>• Short-term (1 day – 1 week) disruption to critical utility or utility corridor. |
| Low | • Minor (inconvenient) damage to critical utility or utility corridor, OR<br>• Moderate (easily reparable) damage to non-critical utility or utility corridor, OR<br>• Very short (< 1 day) disruption to critical utility or utility corridor. |

### **Table A10.7.** Example of consequences to domestic water supply.

Examples of factors to consider:

- Important factors include landslide path, volume of the landslide, amount of sedimentation, duration of sedimentation, water quality and quantity, extent of damage to works, intake, and storage, effect on chlorinating, cumulative effects (previous slides), and availability of alternative sources of domestic water supply.

| Consequence | Examples |
|---|---|
| High | • Permanent loss of quality; short-term loss of supply. |
| Moderate | • Short-term disruption of quality; short-term loss of supply. |
| Low | • Water quality degraded but potable; no disruption or damage to water supply infrastructure; effect < 1 day. |

### **Table A10.8.** Example of consequences to fish habitat (includes riparian management area).

Examples of factors to consider:

- Important factors include landslide path, volume of the landslide, amount of sedimentation, duration of sedimentation, hydraulic connectivity, location of deposition zone relative to fish stream or watercourse connected to fish stream, deposition zone size/volume, and type of deposition material.
- Cumulative effects and previous slides may increase or decrease consequence rating.
- For a high consequence rating:
  - consider where the permanent loss is located (directly or indirectly downslope of a failure site),
  - consider the stream channel and the riparian zone,
  - consider the requirements of the federal *Fisheries Act*. Federal legislation takes precedence over provincial legislation.

| Consequence | Examples |
|---|---|
| High | • Permanent loss of habitat; likely not feasible to restore habitat, but sediment should be controlled at source. |
| Moderate | • Habitat damaged but can be restored through intervention; source of sediment can be controlled. |
| Low | • Limited habitat damage that can be eliminated or controlled through natural processes within 1 year. Source of sediment can be restored to pre-landslide condition through minor work (e.g., grass seeding, silt fences). |

**Table A10.9.** Example of consequences to wildlife (non-fish) habitat and migration.

Examples of factors to consider:

- Important factors include landslide path, area of landslide track, type of deposition material, species present, species status (red to yellow), rarity of affected habitat, and size of home range.
- The major effect of a landslide on wildlife is on the habitat of that species, or on the habitat of the species on which that species depends. Effects on migrating wildlife are minimal.
- Is rehabilitation/mitigation possible? Successful mitigation depends on species and habitat.

| Consequence | Examples |
|---|---|
| High | • The affected species is rare, endangered, or a management concern (e.g., identified wildlife), OR<br>• Permanent loss of habitat or migration route; likely not feasible to restore habitat, OR<br>• Permanent adverse effects on wildlife population need to be assessed, OR<br>• The affected area is large relative to the locally available habitat and/or the affected habitat is rare (there is no suitable adjacent habitat). |
| Moderate | • Habitat damaged or migration route temporarily interrupted but can be restored through intervention, OR<br>• Wildlife populations disrupted but no permanent effect on population, OR<br>• The affected species is not rare or endangered, although it may be of management concern (e.g., identified wildlife), OR<br>• The affected area is being managed for wildlife, has been set aside for wildlife, or has been identified as wildlife habitat (in a resource plan). |
| Low | • Limited damage to habitat; no disruption to migration route, OR<br>• Damage could be restored through natural processes within one growing season, OR<br>• The wildlife species is not of management concern (e.g., it has not been designated as rare, endangered, or as identified wildlife), OR<br>• The affected area is not being managed for wildlife, has not been set aside for wildlife, and has not been identified as wildlife habitat (in a resource plan). |

**Table A10.10.** Example of consequences to visual resources in a scenic area.

Examples of factors to consider:

- Important factors include expected landslide path, size and numbers of landslides in perspective view area, and duration of visible adverse effects on scenic areas.
- Applies only where there is reasonable expectation for visible alteration of the landscape in scenic area (there are no legal obligations to manage visual resources outside a scenic area).
- Criteria used to develop Visual Sensitivity Class (VSC) ratings include: visual absorption capability (the measure of the landscape's ability to accept change), biophysical rating (measure of topographical relief and vegetation variety), viewing condition (viewing duration and proximity), and viewer rating (numbers of people and their expectations).

| Consequence | Examples |
|---|---|
| High | • Visible site disturbance of any amount within scenic area designated as Visual Sensitivity Class (VSC) 1 or 2. |
| Moderate | • Visible site disturbance up to 7% of the landform area as measured in perspective view (for both in-block and landform situations) within scenic area designated as Visual Sensitivity Class (VSC) 3 or 4, and where visible adverse effect on a scenic area should have disappeared by the time visually effective green-up is achieved. |
| Low | • Visible site disturbance up to 15% of the landform area as measured in perspective view (for both in-block and landform situations) within scenic area designated as Visual Sensitivity Class (VSC) 5, and where visible adverse effect on a scenic area may not have disappeared by the time visually effective green-up is achieved. |

**Table A10.11.** Example of consequences to timber values.

Examples of factors to consider:

- Applies where there is no threat to human life or bodily injury. If there is, refer to "Consequences to human life and bodily injury" table.
- Applies where there is no threat of damage to building, structure, land, resource, recreational site and resource, cultural heritage feature and value, and other feature. If there is, refer to "Consequences to public and private property" table.
- Important factors include landslide size, age of merchantable timber, time remaining to reach a harvestable state, and timber value ($\$/m^3$).
- Note shift from "consequences to soil productivity or growing site potential" to simply "consequences to timber values." It is assumed that areas of high-value timber directly correlate to areas of high soil productivity.

| Consequence | Examples |
|---|---|
| High | • Destruction of mature harvestable timber stands and the timber value is in the top third for the region (implies a high site productivity area), and the ground area adversely affected by the landslide is large. |
| Moderate | • Destruction of mature harvestable timber stand and the timber value is in the middle third for the region, and the ground area adversely affected by the landslide is large, OR<br>• Destruction of juvenile timber stands that are within about 20–35 years of potential harvest and the future timber value at a harvestable stage will be in the top or middle third for the region, and the ground area adversely affected by the landslide is large. |
| Low | • Destruction of mature harvestable timber stands and the timber value is in the top third for the region, and the ground area adversely affected by the landslide is small, OR<br>• Destruction of mature harvestable timber stand and the timber value is in the bottom third for the region (implies a low site productivity area), and the ground area adversely affected by the landslide is large, OR<br>• Destruction of juvenile timber stands that are more than 35 years away from potential harvest and the future timber value at a harvestable stage will be in the top or middle third for the region, and the ground area adversely affected by the landslide is large. |